PB81-176646

Seminar on Water Quality Management Trade-Offs (Point Source vs Diffuse Source Pollution)

(U.S.) Environmental Protection Agency
Chicago, IL

Sep 80

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-905/9-80-009	2.	3. RECIPIENT'S ACCESSION NO. PB81 176646
4. TITLE AND SUBTITLE "Seminar on Water Quality Management Trade-Offs" (Point Source vs Diffuse Source Pollution)		5. REPORT DATE September 1980 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Compiled by: Ralph G. Christensen and Clifford Risley, Jr.		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Environmental Protection Agency Great Lakes National Program Office 536 South Clark Street, Room 932 Chicago, Illinois 60605		10. PROGRAM ELEMENT NO. A42B2A 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U. S. Environmental Protection Agency Great Lakes National Program Office 536 South Clark Street, Room 932 Chicago, Illinois 60605		13. TYPE OF REPORT AND PERIOD COVERED Conference Report 14. SPONSORING AGENCY CODE U.S. EPA-GLNP

15. SUPPLEMENTARY NOTES

Conference Committee-Ralph G. Christensen, U. S. EPA; Carl D. Wilson, U. S. EPA; Clifford Risley, U. S. EPA; Orville Macomber, U. S. EPA; Donald Urban, U. S. DA-SCS

16. ABSTRACT

This report is a collection of technical papers presented at the "Seminar on Water Quality Management Trade-Offs" Point Source vs Diffuse Source Pollution held in Chicago, Illinois September 16-17, 1980 at the Pick Congress Hotel. Seminar speakers were selected for their expertise in the different areas of point and diffuse source pollution. Many were principal investigators of Section 108(a) and Great Lakes Program demonstration project grants. The seminar pointed out the need for nonpoint source control implementation to meet 1983 water quality goals.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water Quality Sediment Erosion Land Use Land Treatment Wastewater Treatment Nutrients Phosphorus availability Pollutant Loadings Treatment costs Institutional		

18. DISTRIBUTION STATEMENT Document is available to the public through the National Technical Information Service Springfield, Virginia 22151	19. SECURITY CLASS *(This Report)* NA 20. SECURITY CLASS *(This page)* NA	21. NO. OF PAGES 400 22. PRICE

EPA Form 2220-1 (9-73)

☆ U. S. Government Printing Office: 1981 750-799

United States
Environmental Protection
Agency

Great Lakes National
Program Office
536 South Clark Street
Chicago, Illinois 60605

EPA-905/9-80-009
September 1980

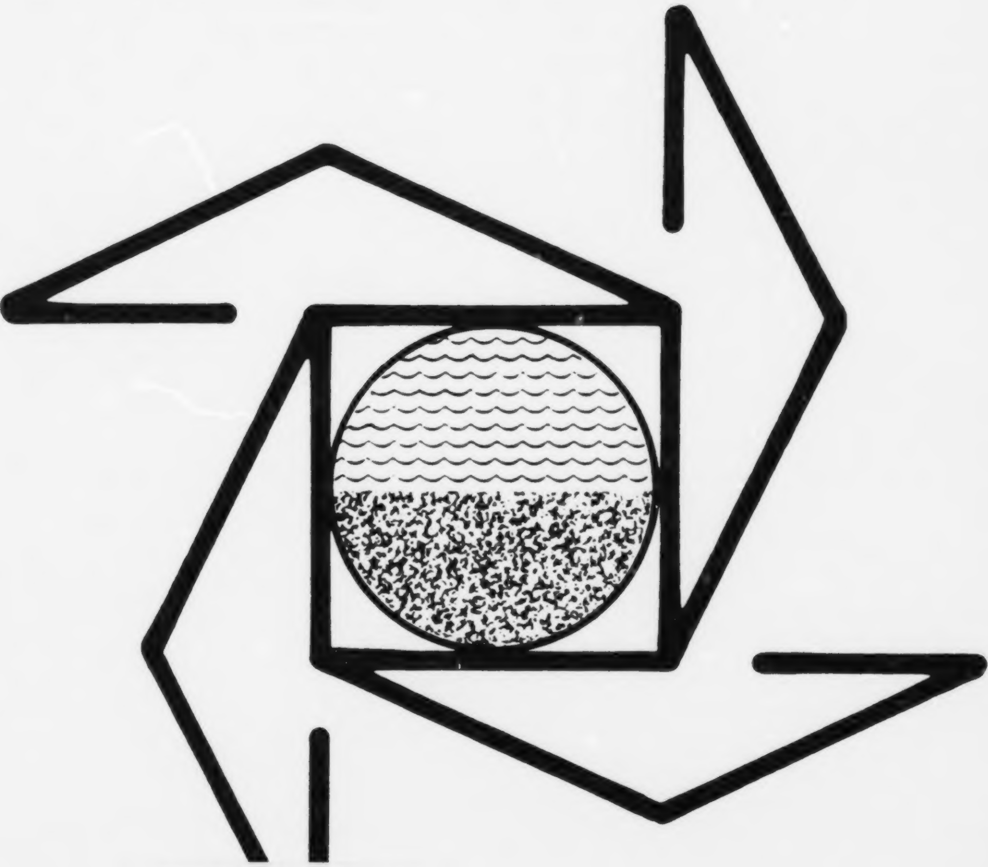
PB81-176646

EPA

Seminar on Water Quality Management Trade-Offs

Point Source vs. Diffuse Source Pollution

(Conference)
September 16-17, 1980
Chicago, Illinois



PRODUCT OF:
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

FOREWARD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

The report contributes to the knowledge essential if the United States Environmental Protection Agency is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost-effective and provide adequate protection for the American public.

The Great Lakes National Program Office (GLNPO) of the United States Environmental Protection Agency, was established in Region V, Chicago to provide a specific focus on the water quality concerns of the Great Lakes. GLNPO provides funding for Great Lakes demonstration grants under Section 108(a) as well as provides personnel support to the International Joint Commission activities under the U.S.-Canada Great Lakes Water Quality Agreement.

Several land use water quality studies have been funded to support the Pollution from Land Use Activities Reference Group (PLUARG) under the Agreement to address specific objectives related to land use pollution to the Great Lakes. This report describes a methodology for integrating point and diffuse source control practices and costs in both large and small watersheds.

The conference committee consisted of Ralph G. Christensen, Section 108(a) Coordinator; Carl D. Wilson, Regional Nonpoint Source Coordinator; Clifford Risley, Regional Research and Development Representative; Don Urban, USDA - Soil Conservation Service; and Orville Macomber, Center for Environmental Research Information.

We hope that the information and data contained herein will help planners and managers of pollution control agencies make better decisions for carrying forward their pollution control responsibilities.

Madonna F. McGrath
Director
Great Lakes National Program Office

EPA-905/9-80-009
September 1980

SEMINAR ON WATER QUALITY MANAGEMENT TRADE-OFFS

(Point Source vs. Diffuse Source Pollution)

Conference

Held at
Pick Congress Hotel
520 South Michigan Avenue
Chicago, Illinois

September 16-17, 1980

Conference Assistance
by
Center for Environmental Research Information
-Technology Transfer-
Cincinnati, Ohio

Sponsored & Published
by

Section 108(a) Program
Great Lakes National Program Office
U. S. Environmental Protection Agency
536 South Clark Street, Room 932
Chicago, Illinois 60605

Table of Contents

Page

Call to Order 1
Clifford Risley, JR. R&D Representative, USEPA, Chicago

Welcome 3
John McGuire, Regional Administrator, USEPA, Chicago

Congressional Intent of Clean Water Act and Amendments 7
Jeff Nedelman, Administrative Assistant to Senator Gaylord Nelson

Water Quality Issues and Conference Overview 13
Madonna F. McGrath, Director, Great Lakes National Program Office
USEPA, Chicago

Section 208 Program
Peter Wise, Director, Water Planning Division, USEPA, Washington, D.C.
(No paper submitted)

Prime Farmland and Water Quality 19
Keith K. Young, Soil Scientist, USDA-SCS, Washington, D.C.

AST/AWT Policy Issues 27
Jeffery J. Gagler, Water Quality Policy Section, USEPA, Chicago

Federal Policy in Floodplain/Wetland Regulation 33
Ronald L. Mustard, Chief, EIS Review, USEPA, Chicago

U.S.-Canada Great Lakes Water Quality Agreement-Impact on U.S. Policy 37
Kenneth Walker, Secretary, Great Lakes Water Quality Board, IJC
Windsor, Canada (Dan Bondy)

State/EPA Agreements: A State/Federal Partnership 43
David Stringham, Assistant to Regional Administrator, USEPA, Chicago

WQM Plans, Status, Quality, Integration and Implementation 47
William G. Benjey, Chief, Ohio WQM Section, USEPA, Chicago

Water Quality Standards--Integration 53
Michael MacMullen, Chief, Water Policy Section, USEPA, Chicago

Effects of Pollutants on Human Health 55
Leland J. McCabe, Director, Health Effects Research Laboratory
USEPA-Cincinnati

Sources of Pollutants to the Great Lakes 63
W. Ronald Drynan, Senior Engineer, IJC, Windsor, Canada

Tributary Loads and Effects 75
Nelson Thomas, Chief, Large Lakes Research, USEPA, Grosse Ile, MI

Page

Land Treatment of Municipal Wastewater 77
Al Wallace, Dept. of Civil Engineering, University of Idaho
Moscow, Idaho

Costs of Wastewater Treatment 81
James A. Hanlon, Chief, EEB, Water Division, USEPA, Chicago

A Management Technique for Choosing Among Point and Nonpoint Control Strategies 87
Part 1-Theory and Process Framework
William Sonzogni, Water Resources Specialist, GLBC, Ann Arbor, MI

Recap of Previous Day's Program and Goals for Today 125
Carl D. Wilson, NPS Coordinator, USEPA, Chicago

A Management Technique for Choosing Among Point and Nonpoint Control Strategies 129
Part 2-A River Basin Case Study
Timothy Monteith, Water Resource Engineer, GLBC, Ann Arbor, MI

BMP Cause and Effect Relationship by Simulation 163
Larry Huggins, Agricultural Engineering, Purdue University
Lafayette, Indiana

Practical Uses of ANSWERS Model in BMP Planning 177
Daniel McCain, District Conservationist, USDA-SCS, Fort Wayne, IN

Water Quality: Sediment and Nutrient Loadings from Cropland 183
Darrell Nelson and Ed Monke, Purdue University, Lafayette, IN

The Variety of On-Site Treatment System Failure 203
Al E. Krause, Environmental Scientist, USEPA, Chicago

Mill Creek Pilot Watershed Study on Pesticide Fate In An Orchard Ecosystem: Development and Presentation of the Experimental Data Base 207
Matthew Zabik, Pesticides Research Institute, Michigan State University, Lansing, MI

Livestock Inputs and Effects 225
Frederick Madison, Soil Scientist, University of Wisconsin
Madison, WI

Upstream Point Source Phosphorus Inputs and Effects 227
David Baker, Professor, Heidelberg College, Tiffin, Ohio

Sediment and Phosphorus Transport 241
Stephen Yoksich and John Adams, US Army COE, Buffalo, NY

Bioavailability of Phosphorus Sources to Lakes 279
Terry Logan, Professor, Ohio State University, Columbus, Ohio

Water Monitoring Program-Planning for 1981 293
William Sanders, III, Director, S&A Division, USEPA, Chicago

Page

Conservation Tillage Practices to Control Agricultural Pollution 301
John Crumrine, Manager, Honey Creek Watershed Project, Tiffin, Ohio

Nonpoint Source Pollution in Urban Areas 309
James Baumann and John Konrad, Wisconsin Department of Natural Resources, Madison, WI

(NURP) National Urban Runoff Program 323
Douglas A. Ehorn, Chief, Michigan WQM Section, USEPA, Chicago

High Flow Water Quality Standards 329
Lyman Wible, Chief Planner, SEWRPC, Waukesha, WI

Biological Indices or a Measure of Water Quality 355
James Gammon, Professor, DePauw University, Green Castle, IN

Biotic Impact of Organic and Inorganic Sediments 365
James O. Bland, Ohio WQM Section, USEPA, Chicago

Conference Summary 377
Clifford Risley, Jr., Regional R&D Rep., USEPA, Chicago

List of Attendees 383

CALL TO ORDER

Clifford Risley, Jr.
Senior Science Advisor
US EPA, Region V

Good morning, Ladies and Gentlemen. Welcome to the Seminar on Water Quality Management Trade-offs.

I want to give you a few words of background regarding this seminar. For many years, Region V of EPA has been very much concerned with the problem of evaluating and controlling non-point source pollution. We have sponsored many projects to give us a better understanding of each of the elements in this problem. This work ultimately led to a discussion among those involved in non-point source pollution control regarding the need to put it all together into a process that we could use to evaluate non-point abatement costs and compare them to conventional treatment or point source costs. We feel there is a great need for a method of doing this, in as simplified a manner as possible, for all water quality managers. As an outgrowth of our discussion of this need, we decided that one of the best ways to precipitate this kind of product was to put together this seminar. That is the "why" of this particular seminar.

We have brought together here, today, many of the people who have been working quite a few years on various parts of the problem; to give you an idea of the kind of work that has been done; the kind of knowledge that is available and the sources of this knowledge, so you will know who is who in these complex studies.

It is now my pleasure to introduce to you, Ms. Madonna McGrath, Director of the Great Lakes National Program Office, EPA Region V, who will be your moderator for the first session.

Welcome
by
John McGuire *
Regional Administrator
USEPA, Region V, Chicago

I am happy to welcome you to this seminar which we have entitled "Seminar on Water Quality Management Trade-offs, Point Source vs. Diffuse Source Pollution." Our Region V Environmental Protection Agency, Great Lakes National Program Office and the EPA Center for Environmental Research Information have programmed this seminar to address water quality issues and goals that hopefully will help us all to have a better understanding of how to plan and manage a water quality control program.

The Great Lakes National Program Office, I speak of, became operational, with headquarters in Chicago, in December 1977. GLNPO's main function is to conduct surveillance and coordinate research and special studies in the eight Great Lakes States. GLNPO also provides technical support and remedial programs for EPA's nonstop fight against all forms of pollution in the Lakes, the largest freshwater system in the world.

GLNPO coordinates its efforts and cooperates with other Federal agencies, with State and local governments, and with university research programs. GLNPO also works closely with these counterparts in Canada, which shares the boundaries of and concern for the Great Lakes.

The Center for Environmental Research Information, headquartered at Cincinnati is the Agency's technology transfer specialists. We appreciate their assistance in preparing this program.

The purpose of this seminar is to discuss a number of water quality issues and policy issues related to control of both point source and diffuse source pollution. At present there is no accepted methodology for integrating point and diffuse source controls and for comparing the costs associated with them.

---

* Given by Madonna F. McGrath, Director, Great Lakes National Program Office, for John McGuire.

The legislative mandate given to the USEPA for protecting our water is Public Law 92-500, and its amendments. A responsibility to manage both point source and diffuse sources of pollution are spelled out for us. In addition to the U.S. mandate we have a responsibility to Canada for our activities on the Great Lakes. Under a U.S./Canada Great Lakes Water Quality Agreement signed by the two countries in 1978 we share a common concern for the pollution control of the international boundary waters that includes all of the Great Lakes and their tributaries.

One of the reference of the Water Quality Agreement was directed by the International Joint Commission to inventory land-use activities and their pollution effects on the Great Lakes.

To do that task USEPA, through Region V, funded four major pilot watershed studies along with several other studies to prepare information and remedial recommendations to best reduce and control diffuse source pollutions to the Lakes. Three major sediment control projects and one urban drainage project were funded under Section 108(a) to provide data for use in developing implementation programs in the Great Lakes basin. The U.S. Army Corps of Engineers under Section 108(d), Lake Erie Wastewater Management Study, has done extensive study and demonstration in Lake Erie basin to reduce and or control sediment. Approximately $19 million in addition to Section 208 Areawide Wastewater Management Planning has been spent on diffuse source study and demonstration since 1972 in Region V.

In the Great Lakes basin the USEPA has provided $5 billion of the public funds to support additional State and local government funds for treatment and control of municipal wastewaters.

The presenters at this seminar will provide you with data and information that they have personally been involved with. They will be able to answer most of your questions. We have a great amount of point and diffuse source water quality data in Region V. Based on the data we have we are proposing a methodology that will help to evaluate cost effective trade-offs necessary to achieve a prescribed water quality goal on a watershed basis. This might tell us that in one watershed diffuse source control is the most cost effective while in another watershed point source control is the most cost effective. The methodology will also help to evaluate what might be the best mix of point and diffuse source controls that together would be most cost effective to achieve a water quality goal.

As we proceed through the two days of this conference I hope you will take advantage of the expertise and experience of the presenters to help you with achieving our water quality goals.

CONGRESSIONAL INTENT OF CLEAN WATER ACT AND AMENDMENTS

Jeff Nedelman
Administrative Assistant to
Senator Gaylord Nelson

It is always a pleasure to come back to Chicago. I enjoy looking at Lake Michigan and realizing that it is still a beautiful lake thanks to the efforts of Region V of EPA. I saw Madonna, several weeks ago, when Senator Nelson and I were visiting your marvelous lab at Duluth. We were getting a briefing on Great Lakes water quality issues, research funding, programs under way, and a discussion of concerns which we both share. Madonna asked if Senator Nelson would be available to speak to you today. It was his desire to do so, but with the election only 15 days away, the press of events has required him to reschedule his time day by day and he was simply unable to get here today.

The Congressional Intent of the Clean Waters program as it applies to the Great Lakes is my topic. This is basically the third time I have had an opportunity to speak about water quality issues. The first time was several years ago at an International Joint Commission (IJC) meeting in Windsor, Ontario. I delivered a speech which was euphemistically called "Americas Great Lakes Programs and the Bureaucratic mess in the U.S." which got quite a little bit of attention. A year or so ago, Senator Nelson spoke to the Great Lakes Fisheries Executive Meeting in Miluakee. His speech was titled

"Progress; albeit slow--New Problems on the Horizon"

He emphasized that progress was being made but much too slowly. He tried to put this in perspective by taking us back a few years outlining some of the trade offs that have to be made in contemplating the future.

The 1970's saw an enormous growth of public concern and public activity regarding the environment. There were a number of catalysts that came to the fore. For example, Gaylord Nelson happened to be invited to give an address on Nuclear Power at Berkely right after the campus protests. Flying back, he picked up a magazine that had a long piece about the decried confrontations on the campuses about the Viet Nam War. It decried the energy and activity applied to the war and suggested that the government should apply the same kind of energy and activity to domestic issues.

The Senator made the logical comparison between the Educational and Informational Programs on the war and the need for the same level of effort on the Environment. This led to Earth Day in April of 1970. From the 70's we see a cry from the public for more legislation to protect the environment. EPA came along, Earth Day, Strip mine legislation, Clean Air, SCOPE (Student Council on Protecting the environment) among many others. When EPA was established in Chicago, I met a lot of people who were working quietly and diligently to clean up the environment and who were enormously helpful in supplying good information to our office which helped us develop our legislative position. I think, in all honesty, that in the late 60's and 1970's we were making suggestions. At the time when the legislation was created in Congress, we were guessing at the scope of problems, we were guessing at the contributions, we were guessing at the costs. We did not really have any knowledge of how long it would take. Nevertheless, we set a goal, we set a deadline and we began.

We set a goal of a quality environment; the fishable, swimmable, water quality by 1985. It still seems to us to be a reasonable goal. However, there are new considerations. The 1980's, it seems to me, are like the 1960's.

There is a new vernacular, a new awareness on both sides that clean water is desirable and attainable. But we have new problems that we didn't know existed before. The question is not one of whether we shall have clean water but the question is "How clean is clean?" and "How quickly can we get there?" The Congressional staff is constantly discussing how much it is going to cost and where is the money coming from?

In my judgment, the whole movement of the 60's toward a high quality environment remains today as the concern of the highest priority for the public, second only to our national security. What we are talking about 10 years after Earth Day, are still questions affecting the productivity of our oceans and our lakes. These are of high concern, especially to the hundred millions of people living around the Great Lakes.

We have seen some progress but it has been slow. For example, the Reserve Mining situation where 67,000 tons of carcinogenic material were dumped yearly into Lake Superior. It took eleven years of court action to stop the 20 years of dumping. There are many other examples of slow but sure progress. We have been putting together all the parts of the clean up process but I am not sure we understand all the parts. The thrust of EPA's program has been to gain a basic scientific understanding of how these enormous bodies of water work. Where is the pollution coming from? What effects does it have? How do we get it out?

What we have been seeing in Congress is, in my view, a lack of sensitivity to these problems. EPA is just not getting the money that is needed for Great Lakes. This year EPA spent $18,000,000 in travel and only $2,000,000 on the Great Lakes. We have been going back and forth on this issue for many years. The Congressional supporters of the Great Lakes keep putting items into the budget and the budget committee keeps knocking it out. To members of Congress from the Great Lakes States and the Northeast, this is recognized as a great problem.

Basically, we have about ten years if the degradation continues. The Great Lakes program is being funded very minimally. By comparison, look at the Sewage treatment plant construction program. It is in the order of three to four Billions of Dollars. These programs are decided by Congress and the appropriations made and EPA has little choice but to do those things which Congress appropriates the money for.

William Proxmire, Chairman of the Budget Committee proposed taking 2 million dollars out of Sec. 314 funds to pay for EPA salary increases. We fought against this and therefore we have bad news for those expecting a pay raise. I don't think you are going to get it.

Section 108 program has had no increases for years. The Office of Planning and Management constantly refers to the billions of dollars in the Sewage Treatment Plant Construction which goes in part to Milwaukee, Chicago and Detroit and assumes this takes care of Great Lakes needs. But of course it can't be used for the Great Lakes Research needs.

The Administration requested of Congress in April that 3.5 Billion dollars of the Construction money be deferred. We objected because this would hit Wisconsin very hard; it would hit the Great Lakes very hard. It took four of five months of discussion and action but the motion to overturn this appropriation deferment carried unanimously in the Senate budget committee and it carried unanimously on the floor of the Senate. Despite all the talk of the necessity to tighten the belts and to batten down the hatches in federal spending, Gaylord Nelson successfully led the fight to continue this funding. The support was there in the committee and in the Senate. You just cannot get this support for 8.6 Billion dollars in these times without the members of Congress and members of the Senate understanding that there is wide base public support for these programs in their home states.

In terms of new problems and trade offs that are facing Congress in the next year or so, Environmental issues have been constantly before Congress. We have had fights over water policy but even more over public works projects.

Both the Clean Air Act and Amendments to the Water Quality Act come before Congress next year. From everything that I hear, we can expect 1981 to be a major test of the nation's resolve to meet the goals that were spelled out in the Water Quality Act. Congress needs to affix the direction of the enormous costs that have to be spent to achieve the goals. It needs to set the new round of time tables for moving ahead.

According to EPA estimates 54 Billion dollars will be needed to complete all secondary treatment plants and advanced waste treatment projects. With inflation in the construction industry running to more than 50% we are not making any real headway at all. EPA itself estimates that with a zero inflation rate it would take twenty years to complete all the mandated projects.

That brings us to the second issue "Can we wait twenty years?" The answer is "No, we cannot." The city of Milwaukee is an example of many other cities which have needs beyond the current level of appropriations. How are we going to get these major cities to move along to meet their mandated time tables when the Federal funds come to the states on a much slower time table? How can the cities come up with sufficient funds on their own?

The third issue is "Why should Congress increase the appropriations when about 50% of the plants on line now operate inefficiently?" The means of achieving proper O&M should be a local responsibility. Congress is faced with a difficult decision regarding funding of O&M costs.

It seems to me that we only have one Great Lakes. They are a national treasure and a national resource that demand high priority. They must be viewed as a long term committment. They cannot be reviewed on a year to year budgetary basis. Where the administration does have discretion, it seems to me, they must exercise that discretion as positive support for the Great Lakes.

I am optimistic about the future of the Environmeental movement. Part of the dialog that takes place in Congress daily deals with clean air, clean water and a safe environment. We can all be thankful for that.

Congress is comprised of many members who, with their staffs, share your concern about the Great Lakes and who are more aware than most what man is doing to the environment. Therefore, we have a very heavy responsibility indeed, to make sure that the programs work, that they are run efficiently, that the public understands the progress we have made and the problems we face in the future. We must be careful not to be doomsayers but to be frank about the problems and the difficulites to be faced and the costs required to solve them.

Water Quality Issues and Conference Overview

Presented By

Madonna F. McGrath

Director, Great Lakes National Program Office

Canada and the United States share a vast and valuable resource - the five Great Lakes, which form the largest freshwater system on earth. One-fifth of the U.S. population, one-quarter of the U.S. industry, and more than one-third of Canada's population depend on the Great Lakes for drinking water, transportation, industrial development, energy production, fishing and recreation. The water quality of the lakes must be maintained or those uses will be lost or greatly impaired.

While many governments, states and agencies share the responsibility for Great Lakes water quality, the prime pollution control efforts in U.S. waters fall within the scope of the U.S. Environmental Protection Agency and the various programs it administers. The goal of EPA's Great Lakes program is to restore and enhance water quality in the Great Lakes basin so that public health, welfare and the environment are protected. To achieve this goal USEPA established the Great Lakes National Program Office. The principal function of this Office is to plan, coordinate and oversee EPA's pollution control programs as they affect waters of the Great Lakes, acting as a catalyst with the EPA Divisions and the States in identifying Great Lakes problems and recommending solutions to them.

Since the U.S. and Canada share a common concern regarding pollution of the lakes the two countries renewed the Great Lakes Water Quality Agreement in 1978. Historic precedent for both the 1972 and 1978 Agreement is the U.S. - Canadian Boundary Waters Treaty of 1909, which specified that neither country is to do anything that would harm Great Lakes waters and threaten the health of citizens of the other country. The implementation of the U.S. portion of that Agreement is the responsibility of my Office, which also provides staff services to Region V's Regional Administrator, John McGuire, in his capacity as Co-Chairman of the International Joint Commission's Great Lakes Water Quality Board.

To accomplish both our national and international goals we conduct water quality surveillance programs and special investigations and provide both the public and other offices with scientific reports and policy recommendations. To assure that citizens are involved and well informed in matters and decisions affecting the Great Lakes our staff prepares brochures, technical reports and other educational materials. The Great Lakes National Program Office also serves as a focal point for communication and cooperation with other groups and agencies involved in Great Lakes activities, as evidenced by this Conference today.

We greatly appreciate the participation of the many agencies which are represented by our speakers and guests in the audience.

The new definitive strategy for activities by the Great Lakes National Program Office calls for concentration of most of our scientific and technical resources on three key areas:

1. The revision and implementation of Great Lakes monitoring to emphasize toxic chemical and nutrient surveillance.
2. Special investigations of serious "hot spots" problem areas, and development of multimedia remedial control programs for them.
3. Increased State involvement in Great Lakes decision-making through the State/EPA Agreement process.

To understand why the Great Lakes National Program Office is concentrating of these areas, it is important to understand the problems that currently plague the Great Lakes.

The most serious threat to the Lakes is the existence of persistent toxic chemicals in Great Lakes water, fish, wildlife and sediments. These substances affect all portions of the Great Lakes in varying degree. Many have the capacity to bioaccumulate; they have been found in the Lakes' fish and wildlife in alarming concentrations. Fish from Lake Ontario are heavily contaminated by Mirex. Lake Michigan fish cannot be sold commercially because of high levels of PCB's. Fish from Lake St. Clair had high levels of mercury that restricted their use for several years.

Toxic substances reach the aquatic environment through direct discharges from industries, in runoff from agricultural and urban activities, and from the atmosphere. While the effect of toxic substances on aquatic organisms is not well understood, severe adverse health effects on mammals and birds are well documented. But we need to learn very much more about how and where these pollutants enter the lakes, how to identify and locate them in the lakes and their tributaries, and to learn about effective management programs to remedy their negative impacts.

While toxic chemcial pollution is receiving a great deal of attention, there still remains the problem of accelerated eutrophication of the lakes by nutrient enrichment. If not controlled, this enrichment and the resulting loss of oxygen can lead to greatly increased costs for treating drinking water, elimination of high-quality fish species, and loss of recreational activities through fouling of beaches, elimination of sport fisheries, and increased algal growths on the hulls of boats and ships that sail the Lakes.

All of the Great Lakes are affected by this process in varying degree, but Lake Erie and Lake Ontario and sheltered areas such as Green Bay and Saginaw Bay are the most severely affected; they have suffered major deterioration in the quality of their fish stocks. Dissolved oxygen depletion in the bottom water of the central basin of Lake Erie has a severe impact on fish reproduction because of fish respiratory problems and changes in chemistry.

Traditionally phosphate discharges to the lakes have been reduced through more stringent requirements on direct municipal and industrial dischargers. But nonpoint sources from rural land runoff, combined sewer overflows, the atmosphere and urban storm runoff also contribute nutrients and sediments to these waters. What mix of point and nonpoint source control measures are needed to slow down the euthrophical processes in the Lakes?

In Region V over the past year we have been a mounmental water quality planning effort come to fruition with the local, state and federal approval of nearly all the regional and state 208 Water Quality Management Plans.

As these plans become more fully developed and more fully utilized, we will expect to see more integration of the Construction Grants 201 program with the implementation of nonpoint source abatement programs so that the total water pollution in any area is regulated in the most cost-effective manner to meet water quality standards. New methodologies for water quality modeling and distribution of wasteload allocations may be needed to meet this goal.

Several types of pollutant source reductions - as opposed to structural measures are often a feature of nonpoint pollution abatement plans. Reductions may be proposed through implementation of appropriate best management practices or better housekeeping practices such as storm sewer cleanups or street sweeping. Nonpoint source abatement may also involve improved management practices of on-line construction - for example, modifications of flow control devices to increase storage capabity and attenuate flow surges in combined sewer systems. What are the options and alternatives in combining such nonpoint abatement techniques with sewage treatment plant construction and other structural pollution abatement technologies?

One source reduction and management method which is appropriate for reducing phosphate discharge to the Great Lakes is to ban the use of high phosphate detergents. Currently, all Region V states but Ohio restrict phosphate detergents, and water quality has shown improvements where restrictions have been effectively enforced. Immediate reduction of phosphorus loads to the Great Lakes may still be realized with an extension of detergent controls to States which have no such controls and whose waste treatment programs are not in compliance with phosphorus effluent limitations.

Although the need for further phosphorus control of the Great Lakes is evident, clear directions of the extent, timing and type of additional controls needed are not readily apparent. The effectiveness of nonpoint source controls, phosphorus bioavailability, and the cost of these remedial measures can now only be quantified in a very incomplete fashion. While there are indications that additional tributary load reductions will be required to meet the International Joint Commission's 1978 target loads, we need to assess the impact of presently recommended controls for toxics and phosphorus and for point and nonpoint loads, especially on Lake Erie and Lake Ontario, before recommending major new programs.

Information shared in this conference about multimedia lake inputs, agricultural demonstration watershed projects, model structures and evaluations, target loading, phosphorus bioavailability, appropriateness of institutional control measures - to name a few of the seminar topics will be used to improve implementation of our present goals and to reduce uncertainties about development of future goals for the Great Lakes. Having this information is essential to your and our need to understand the total Great Lakes ecosystem and the diverse interactions which occur within its chemical, physical biological and societal components. As we develop this kind of understanding we can, together, develop effective management and restoration of the Great Lakes.

PRIME FARMLAND AND WATER QUALITY

by

Keith K. Young*

INTRODUCTION

Food production involves a trade-off with water quality. Whenever the protective cover of vegetation is disturbed and the soil is tilled, the potential for erosion is increased. Increased erosion not only lowers productivity but increases sediment in streams and lowers water quality.

This paper discusses our supply of prime farmland, its effects on water quality, and our need to preserve and conserve it.

WHAT IS PRIME FARMLAND?

Detailed criteria for prime farmland were published in the Federal Register on January 31, 1978. Basically, prime farmland is the land that is best suited to producing food, feed, forage, fiber, and oilseed crops. It has the soil quality, growing season, and moisture supply needed to economically produce a sustained high yield of crops when it is treated and managed using acceptable farming methods. Prime farmland produces the highest yields with minimal imputs of energy and economic resources, and farming it results in the least damage to the environment.

Prime farmland can be cropland, pastureland, rangeland, forest land, or other rural land but not urban and built-up land or water areas. It must either be used for agricultural production or be available for these uses. Certain drained wetlands also meet the criteria, but SCS does not provide technical assistance for draining existing wetlands.

Prime farmland usually has an adequate and dependable supply of moisture from precipitation or irrigation. In general, it also has favorable temperature and growing season, acidity and alkalinity, and salt and sodium content. It has few or no rocks and is permeable to water and air. Prime farmland is not excessively eroded or saturated with water for long periods and is not flooded during the growing season. Slope ranges mainly from 0 to 5 percent.

---

* Soil Scientist, Soil Technology, Soil Conservation Service, Washington, D.C.

HOW MUCH PRIME FARMLAND DO WE HAVE?

There are about 346 million acres of prime farmland in the United States excluding Alaska. Most of this land is in the Corn Belt, followed by the Northern Plains, the Lake States, and the Southern Plains (1). Figure 1 shows the acreage of prime farmland by state and farm production region in 1977. The amount of prime farmland in each state varies greatly, ranging from 38 million acres in Texas to 81,000 acres in Rhode Island.

From 1967 to 1975, about 8 million acres of prime farmland were lost to other uses at an average rate of 1 million acres per year (3). Of this 8-million-acre loss, 6.5 million acres were converted to urban and built-up areas and 1.5 million acres to water areas.

HOW IS IT BEING USED?

Two-thirds of our prime farmland, or 230 million acres, was used for cultivated crops in 1977 (1). This accounts for more than one-half of the 413 million acres of cropland in the United States. Of the 166 million acres of prime farmland that were not in cultivated crops in 1977, there were 42 million acres of forest land, 40 million acres of native pastures and pastureland, 23 million acres of rangeland, and 11 million acres of farmsteads, farm roads, feedlots, and similar lands.

Prime farmland accounts for a large share of cropland in the major farming regions of the United States. In the Corn Belt, which has 22 percent of the cropland in the country, 74 percent of the cropland is prime farmland. By contrast, the Mountain Region has 10 percent of the nation's cropland, only 21 percent of which is prime farmland (1).

Prime farmland produces the largest share of the nation's total crop production and a large portion of the commodities for export. This land significantly helps to reduce the foreign trade deficit. In addition, the use of prime farmland for crops helps to ensure that efficient food, fiber, forage, and oilseed production will continue with the least damage to the environment. The loss of prime farmland to other uses means that more pressure is placed on nonprime lands to meet production demands. Nonprime land generally are inherently less productive and are more erodible, droughty, difficult to cultivate, and more damaging to the environment.

LAND USE AND POLLUTION

The following table shows sheet and rill erosion by selected land uses (1):

Land use	Tons per year (millions)	Tons per acre per year
Cropland	1,969	4.8
Pastureland	274	2.4
Native pasture	72	4.1
Rangeland	1,392	3.4
Forest land	437	1.2
Total	4,144	3.1

The erosion amounts represent tons of soil moved from the field--not tons of sediment. Some of the eroded soil is trapped before it reaches the stream. A strong relationship exists, however, between soil loss and sediment delivery. Generally, the greater the erosion, the greater the amount of sediment delivered to a stream. The table shows that cropland accounts for nearly one-half of the total annual erosion in the U.S. and also has the highest average per acre loss.

Rangeland also accounts for large amounts of eroded soil, some of which reaches streams. Together, cropland and rangeland produce over 80 percent of sheet and rill erosion from agricultural land.

Because relatively larger amounts of chemicals are applied on cropland than on other agricultural lands, sediment from cropland is more environmentally destructive than sediment from other agricultural lands. The PLUARG study (2) discovered that cropland accounts for higher loads of sediment, total phosphorus, and total nitrogen than land in all other uses except urban developments. The study concluded that intensively farmed fine textured soils near watercourses contribute the major portion of water pollutants.

PRIME FARMLAND AND POLLUTION

Of all U.S. cropland, that which is prime farmland has the lowest rate of erosion. By capability class, estimated average annual sheet and rill erosion on U.S. cropland is as follows:

Capability class and subclass	Erosion (ton/acre/yr)
I	3.0
IIe	5.0
IIIe	6.9
IVe	8.7
VIe	14.9
VIIe	15.4

Most prime farmland is in class I or II. The average annual soil loss for prime farmland is less than 5 tons per acre--assumed to be an acceptable level under which soil productivity can be maintained for a long period of time. Nonprime cropland soils have much higher rates of erosion--at unacceptable levels that degrade the potential productivity of the soil. On a per-acre basis, the nonprime farmland soils furnish the greatest amount of sediment and chemicals to streams.

Despite the benefits of prime farmlands, however, they also produce pollutants. The prime farmland soils are naturally fertile but respond well to commercial fertilizer so farmers apply it--along with pesticides--for optimum crop production. Because of the relative large acreage of prime farmland under cultivation (two-thirds of the total cropland), total erosion and sediment from prime farmland are significant. Prime farmland produces almost half the amount of erosion from all cropland. Some prime farmland soils are flooded at times--though generally not during the growing season--and thereby contribute sediment and other pollutants to streams.

Prime farmland soils are more likely to have seasonal water tables closer to the surface than nonprime farmland soils. As a result, leachates from chemicals applied to prime farmlands are more likely to reach underground water supplies.

On some prime farmland that is irrigated, another water quality problem arises from improper irrigation systems and water management. If more water is applied than the plants can use or the soil can hold, the excess runs off the surface or percolates through the soil, carrying large volumes of salts to streams and rivers.

Prime farmland underlain by coal or other valuable mineral deposits presents another problem that could affect water quality. Surface mining can cause serious environmental damage unless proper mining and reclamation techniques are used. Acid materias and rock fragments must be buried and the soil replaced in such a way as to restore the original soil productivity and minimize water pollution from sediment and acid runoff.

PRIME FARMLAND POLICY

Preservation

Preservation of prime agricultural land is a federal policy. The National Environmental Policy Act (NEPA) set the federal policy "to preserve important historic, cultural and natural aspects of our national heritage and maintain, wherever possible, an environment which supports diversity and variety of individual choice." This policy was restated in a joint memorandum to agency heads from USDA and the Council on Environmental Quality. The policy stated that prime agricultural land, including prime farmland, should not be irreversibly converted to other uses unless other national interests override the importance of preservation or otherwise outweigh the environmental benefits of protection.

The Department of Agriculture is committed to assisting federal agencies in the identification of prime farmland. The Soil Conservation Service has published about 400 prime farmland maps of high priority counties. The rest are scheduled for publication in the mid-80's. The prime farmland soils are identified in counties in which soil surveys are available (about two-thirds of the 3000 counties in the U.S.)

The Department of Agriculture also evaluates draft environmental impact statements with respect to impacts on prime and other important farmlands.

Conservation

Conservation of prime farmlands--and all other lands as well--is promoted through policies of the Department of Agriculture. In general, the Soil Conservation Service (SCS) provides technical assistance to farmers, the Agriculture Stabilization and Conservation Service (ASCS) provides cost sharing, and Farmers Home Administration (FmHA) provides low-cost loans for implementation of conservation work. The Science and Education Administration (SEA) provides research, demonstration, and education.

Salinity Control

Salinity control on certain irrigated lands that include some prime farmland has been mandated by Congress. The Colorado River Basin Salinity Control Act of 1979 (P.L. 93-320) authorizes certain activities to reduce salinity problem in the Colorado River Basin. The first study completed the 60,000-acre Grand Valley Unit, showed that a locally acceptable program of improved onfarm irrigation practices could reduce salt loading of the Colorado River gy 130,000 tons annually.

Prime Farmland Restoration

The Surface Mining Control and Relamation Act of 1977 (P.L. 95-87) set forth procedures for minimizing environmental degradation. The Department of Agriculture was given responsibility for reviewing surface mining and reclamation plans on all prime farmland and for making recommendations to the state regulatory agency.

SUMMARY

With all cropland there is a trade-off--food production for lower water quality. However, when prime farmland is used for crop production the detrimental effects on water quality are minimized. The loss of prime farmland puts more pressure on marginal lands which are less productive, more erodible, and produce more pollutants.

Environmental policy provides emphasis on preservation and conservation. Much remains to be done, however, to preserve out best cropland from irreversible conversions, protect its productivity from erosion, and minimize damage to the environment.

References

(1) USDA. 1978. 1977 National Resource Inventories.

(2) Sonzogni, William C. 1980. Environmental Pollution from land runoff. Environmental Science and Technology 14(2): 148-153.

(3) USDA. 1980. Appraisal review draft, Part I, Soil and Water Resource Conservation Act (RCA).

AST/AWT POLICY ISSUES

by

Jeff Gagler*

With the institution of Public Law 92-500, ambitious water quality goals were established. These included meeting secondary treatment by 1977 and "Fishable/Swimmable" by 1983. In the process of trying to meet these goals we have become entangled in controversy over advanced waste treatment (AWT) issues. On March 9, 1979, EPA issued PRM 79-7, to more intensely review advanced treatment projects in response to a directive issued by the Appropriations Conference Committee. Suit was filed against EPA on December 28, 1979, by the State of Illinois. In general, the suit claimed that the review policy was preventing the State from achieving the goals of the Clean Water Act. A settlement agreement was signed between Illinois and EPA on April 22, 1980.

Notwithstanding the fact that the Agency's initial review procedure was successfully challenged by the State of Illinois and has been modified to screen out low cost technologies form further review, the policy issues raised from the initial review procedures will not go away by merely changing those procedures. These and other issues go to the very heart of the National Water Quality Management Program. The issues are as follows:

A. Water Quality Standards Issues

1. There is a need to have a clear definition for the term "Fishable/ Swimmable" as it applies to water quality for protecting and preserving the ecology of aquatic communities as they exist in waters across this country.

---

* Environmental Scientist, Modeling Coordinator, Policy Section, U. S. Environmental Protection Agency, Region V.

2. Efforts must be made to provide procedures and guidance for establishing consistency in classifying our waters and applying designated uses.

3. A clear and concise guideline must be formulated to determine "attainability" of the receiving water use.

   a. This guidance should require that the test for "attainability" be applied against the classification and designated uses of stream segments and not water quality criteria. The water quality criteria should be based not solely on chemical, but also physical and biological conditions necessary to support a receiving water use.

4. The "Red Book" presumptive applicability policy for water quality standards must be clarified. There must be a clear understanding for accepting and supporting the State's rights to recommend more restrictive or less restrictive criteria as recommended by the "Red Book" when justifiable.

5. There is an urgent need to develop simplified procedures for adoptions, approval, disapproval, and promulgation of water quality standards and use designations.

6. We need a policy which ensures consistency in establishing water quality standards between EPA Regions and States while allowing enough flexibility for recognizing the uniqueness of water quality requiements from Region to Region.

B. Wasteload Allocation Issues

1. There is need for simplified procedures for the adopting, approval, or disapproval of wasteload allocations.

2. Clear and concise guidelines need to address water quality modeling techniques to include:

- a. A clear understanding of what water quality models can and cannot do.
- b. How to apply modeling results for conversion to effluent limitations.
- c. Reevaluation of critical low flow as a base line in all cases.
- d. Guidelines for defining
  - 1) Conditions under which simplified water quality analysis techniques can be justified.
  - 2) Requirements of model calibration and verification.
  - 3) Transferability of water quality analysis from one receiving water to another based on similar characteristics.
- e. Methods for taking into account other source contributors including nonpoint source, combined sewer overflow, and industrial. These need to be evaluated both seperately and collectively to determine major source of impact.
- f. Methods for determining toxic pollution impacts.

C. General Issues

1. We must address the use of flow maintenance to meet standards.
2. We need a mixing zone policy.
3. We need to relook at the antidegradation policy and possibly revise it. At the same time we need methods for implementing that policy.
4. We should expand the use designation and classification scheme to include wetlands

5. We need to recognize the difference and values of intermittent streams and continuous flowing streams and apply policies and guidance accordingly.

The practical significance of these issues is to avoid individual project situations such as:

Where a small community served by an existing lagoon several miles upstream of a lake proposes land application or chemical treatment solely because the lagoon discharge does not meet an imposed phosphorus limit. However, there are no studies to document the significance of the point source discharge versus the nonpoint contribution or to suggest what benefit, if any, might be achieved by controlling the point source phosphorus contribution.

Then there is the situation where a community is required to have an AWT process to meet water quality standards when the receiving stream is channelized or channelization is proposed. Channelization has probably had a greater adverse impact on that stream ecology than could be offset by any benefits gained by applying AWT.

Another situation would be where a community would propose the use of a tertiary sand filter following an existing secondary treatment process to meet effluent limits of 15/20 BOD/SS. What is lacking is a good evaluation of the technical capabilities of the existing facility through fine tuning and improved operations and maintenance.

From an administrative standpoint, economics is the limiting factor for attaining water quality and the focal point for the AWT controversy. However, if we at State and Federal levels can logically see the whole picture rather than just parts and address and make decisions for the issues at hand, we will probably find that there are many more cost effective approaches to meeting the goals of water quality than we have realized. It is the responsibility of the State and Federal Agencies to act or we will surely jeopardize the support of the Public and Congress for meeting the goals and programs of the Clean Water Act.

FEDERAL POLICY ON FLOODPLAIN/WETLAND REGULATION

by

Ron Mustard

Federal Regulation of Wetland or Floodplain use is restricted to specific projects that fall within the scope of regulatory or financial assistance programs administered by the various federal agencies. Under these programs, the use of wetlands or floodplains for development was, in the past, reviewed in the context of policies adopted by each individual agency. These policies were, as a rule, derived independently from one another. In spite of their independent origins, these policies were, for the most part, similar in that they expressed the concerns then current in the scientific community. However, there was a wide degree of variance in the manner in which these policies were applied, and as a consequence, there was a great deal of confusion about the extent of the Federal Government's Commitment to the concept of Wetland and Floodplain Regulation.

In order to establish a true national policy, and to encourage a more uniform and active application of that policy, President Carter, on May 24, 1977, issued executive orders 11988 on Floodplain Management and 11990 on Protection of Wetlands.

Executive order 11988 Established, as a Policy, that:

"Each agency shall provide leadership and shall take action to reduce the rick of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for (1) acquiring, managing, and disposing of federal lands and facilities; (2) providing federally undertaken, financed, or assisted construction and improvements; and (3) conducting federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities."

In carrying out this policy, each agency has a responsibility to identify projects with potential floodplain impacts, consider alternatives that would eliminate or minimize any adverse impacts, and to provide opportunities for public involvement in the process.

As instructed, the water resources council issued guidance on implementation of the executive order on October 1, 1977. Since then, all other federal agencies have completed, or are in the process of completing, ammendments to their regulations or operating procedures that will ensure compliance with the executive order.

In language almost indentical to that used in the Floodplain Executive order, Executive order 11990Established as a policy that:

> "Each agency ahall provide leadership and shall take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agencie's responsibilities..."

The one exemption to the applicability of this policy is to the issuance by federal agencies of permits, licenses, or allocations to private parties for activities involving wetlands on non-federal property. However, the programs affected by this exemption all have strong wetland protection provisions in their own right, and so, in practice, there is no discontinuity in the federal response to proposed activities in wetlands.

In carrying out the policy established by executive order 11990, each agency has a responibility to avoid unnecessary construction in wetlands, and to minimize the impact of those activities that are necessary. Each agency must also provide for early public review of actions affecting wetlands. Most federal agencies amended their regulations or procedures to ensure compliance with this executive order concurrently with the amendments undertaken for executive order 11988.

From the viewpoint of the general public, the most significant aspect of this process is the requirement that federal agencies document the steps that have been taken to comply with the requirements of the executive orders. When a proposed action will impact a floodplain or wetland area, the sponsoring agency must clearly demonstrate that (1) there is no practicable alternative to the proposed action, and (2) that the proposed action includes all particable measures to minimize harm to the affected resources. By requiring that agency compliance with the policies established by the executive orders be specifically addressed and entered into the public records, interested parties are given additional opportunity to review agency actions and to challenge decisions on the grounds of erroneous application of policy. This ability alone will encourage federal agencies to ensure that their decisions are based upon careful consideration of all available information, and are arrived at in a consistant manner.

UNITED STATES-CANADA GREAT LAKES WATER QUALITY AGREEMENT -- IMPACT ON U.S. POLICY

by

Kenneth H. Walker*

The quality of the water in the Great Lakes has been a matter of concern for many decades. Intermittently since 1912, the International Joint Commission has undertaken investigations to determine the extent of pollution and degradation of this irreplaceable resource.

In 1964, the IJC was formally asked by the Governments of the United States and Canada, pursuant to the Boundary Waters Treaty of 1909, to investigate Lake Ontario, Lake Erie and the International Section of the St. Lawrence River to determine the extent of international pollution, identify the sources, recommend remedial measures, and estimate probable costs to carry out such programs.

The IJC report on the lower lakes was completed and presented to the Governments in 1970. It represented a combined effort by experts drawn from the federal governments of the two countries, the Province of Ontario, and the eight Great Lakes states -- New York, Pennsylvania, Ohio, Indiana, Michigan, Illinois, Minnesota, and Wisconsin. These experts served on the Boards and Committees which carried out the necessary scientific and field studies to enable them to advise the Commission on the seriousness of the pollution problems in the lower lakes.

The Commission's report provided a detailed assessment of the water quality and made comprehensive recommendations for action by the Governments of Canada and the United States. One outcome of this report was the Great Lakes Water Quality Agreement which was signed on April 15, 1972.

In this Agreement, the two countries stated their determination to restore and enhance the water quality in the Great Lakes System. They were convinced that the best means to achieve improved water quality in the System was through the adoption of common objectives, the development and implementation of cooperative programs and other measures, and the assignment of special responsibilities and functions to the International Joint Commission.

The Agreement is unique in that while recognizing the rights of each country in the use of the Great Lakes and reaffirming the obligation not to pollute, it expressed the determination of each country to restore and enhance the water quality. Water quality objectives were enumerated. Programs and other measures to achieve the objectives were identified and were to be completed or in the process of implementation by December 31, 1975. Additional powers and responsibilities were given to the International Joint Commission, including: collation, analysis, and dissemination of data relating to water quality, pollution, water quality objectives, and effectiveness of programs; tendering advice and recommendations to the Parties and to state and provincial governments; provision of assistance in coordination of joint activities and Great Lakes water quality research; and reporting at least annually to the Governments and to the state and provincial governments on progress toward the achievement of the water quality objectives.

---

*Great Lakes Regional Office, International Joint Commission, Windsor, Ontario.

The 1972 Agreement set into motion three major activities: (1) the study of water quality of the Upper Lakes; (2) the study of pollution from land use activities in the Great Lakes Basin; and (3) the implementation of remedial measures to mitigate pollution from point sources. These activities required the interaction of federal, state, provincial, and non-government officials.

The 1972 Agreement also provided that a comprehensive review of its operation and effectiveness should be conducted by the Parties during the fifth year after its coming into force. This review was carried out and resulted in the Great Lakes Water Quality Agreement of 1978 which was signed by the two countries on November 22, 1978.

The new Agreement reaffirmed the determination of Canada and the United States to restore and enhance the water quality of the Great Lakes System. While the new Agreement continued many of the provisions of the 1972 Agreement, it also provided new directions for many of the activities, based on experience gained from the former Agreement.

The impact of the Agreement on policies and programs in the United States is extensive. This is evident from the commitment made in Article II of the Agreement which states the purpose as follows:

> The purpose of the Parties is to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem. In order to achieve this purpose, the Parties agree to make a maximum effort to develop programs, practices and technology necessary for a better understanding of the Great Lakes Basin Ecosystem and to eliminate or reduce to the maximum extent practicable the discharge of pollutants into the Great Lakes System.
>
> Consistent with the provisions of this Agreement, it is the policy of the Parties that:
>
> (a) The discharge of toxic substances in toxic amounts be prohibited and the discharge of any or all persistent toxic substances be virtually eliminated;
>
> (b) Financial assistance to construct publicly owned waste treatment works be provided by a combination of local, state, provincial, and federal participation; and

(c) Coordinated planning processes and best management practices be developed and implemented by the respective jurisdictions to ensure adequate control of all sources of pollutants.

There is a wide range of programs established by the Agreement, many requiring action by specific dates. The Agreement establishes two Boards, a Great Lakes Water Quality Board and a Great Lakes Science Advisory Board, to assist the Commission in the exercise of the powers and responsibilities assigned to it under the Agreement. It also calls for a Great Lakes Regional Office of the International Joint Commission to provide administrative support and technical assistance to the two Boards, and to provide a public information service for the programs, including public hearings, undertaken by the Commission and the Boards.

The Agreement has an effect on the policies and programs of the Federal Government as well as those in the states. In addition to a commitment by the Parties to support the many provisions of the Agreement, in Article XI, the Parties specifically commit themselves to seek:

-- The appropriation of the funds required to implement the Agreement;

-- The enactment of any additional legislation that may be necessary to implement the programs and other measures provided for in Article VI; and

-- The cooperation of the State and Provincial Governments in all matters related to the Agreement.

A review of the Agreement indicates that it specifically addresses such topics as: general and specific water quality objectives; water quality standards; pollution from municipal and industrial sources; eutrophication; pollution from agricultural, forestry and other land use activities; pollution from shipping activities; pollution from dredging activities; spills of oil and hazardous polluting substances; hazardous polluting and persistent toxic substances; airborne contaminants; and vessel wastes.

These provisions impact on U.S. programs involving construction grants, enforcement, NPDES permits, water quality standards, phosphorus control and removal, control of toxics, urban drainage, and point and nonpoint sources of pollution.

The Water Quality Board and the Science Advisory Board provide additional opportunities for interrelationships between the United States and Canada and between the federal, state, and provincial governments. The Water Quality Board was established as the principal advisor to the Commission with regard to the exercise of all the functions, powers and responsibilities assigned to the Commission under the Agreement, except for those assigned to the Science Advisory Board. The Board has 18 members, nine from the United States and nine from Canada. Each of the eight Great Lakes states is represented by a senior official of the state agency with environmental responsibility. The United States federal government is represented by the Regional Administrator of EPA Region V who is also the United States Cochairman of the Board.

This arrangement permits a beneficial exchange of advice on programs and problems to take place between the Parties, the IJC, the Board and the states and EPA. Programs which are recommended to the Commission are frequently implemented by the state members of the Board even before the recommendation is officially transmitted through the Parties back to the state agencies.

The Science Advisory Board structure differs radically from that of the Water Quality Board. Its membership contains federal, state, and provincial representation, but also draws its membership from industry, university, and public environmental groups. The Board is the scientific advisor to the IJC and the Water Quality Board. The Board has 16 members plus two ex-officio members who represent the International Association for Great Lakes Research and the Great Lakes Fishery Commission. The U.S. Cochairman is associated with the U.S. EPA Water Quality Laboratory at Duluth.

Both of these Boards have supporting committees, work groups, and task forces which provide additional input into the many Agreement programs. These organizations result in participation by over 216 people in intermediate and senior professional and administrative positions who serve a liaison role in impacting Agreement programs as well as those of the organizations they represent. This involvement in the Agreement functions represents a tremendous investment of manpower in both countries and provides for an exchange of ideas and information among all the jurisdictions and organizations participating.

Time does not permit an examination of all the programs being carried out under the Agreement. I would like to explore briefly two of these programs -- the water quality objectives and their impact on water quality standards, and the significance of the phosphorus control programs.

Water quality objectives were considered the foundation for achieving improved water quality in the Great Lakes System in both the 1972 and the 1978 Agreements. The concept of using water quality objectives as guidelines for preserving or restoring the water quality in the lakes is one of long standing for the IJC. These objectives are goals to be maintained and achieved in the boundary waters through effective pollution control programs in both countries.

Article V (1) in the Agreement states: "Water quality standards and other regulatory requirements of the Parties shall be consistent with the achievement of the General and Specific Objectives. The Parties shall use their best efforts to ensure that water quality standards and other regulatory requirements of the state and provincial governments shall similarly be consistent with the achievement of these Objectives".

The 1978 Water Quality Agreement contains 41 specific water quality objectives. These are constantly being reviewed by the Aquatic Ecosystem Objectives Committee of the Science Advisory Board. The Committee is also developing new objectives on many problem substances.

At the request of the Water Quality Board, the Regional Office just recently completed a report on "A Review of the Impact of Water Quality Agreement Objectives on Water Quality Standards". The purpose of the review was to determine if the Agreement Water Quality Objectives had been used by the jurisdictions in developing their water quality standards and if not, why not?

The conclusion of the review was that the Agreement Objectives have had a decided impact on the water quality standards and objectives adopted by the jurisdictions.

For example, New York State has established a classification of Class A-Special for the International Boundary Waters. In Ohio, 70 percent of the values in the water quality standards for 33 parameters are equal to or more stringent than the Agreement Objectives. In Pennsylvania for 30 parameters, 63 percent of the state values are equal to or more stringent than the Agreement Objectives.

Some jurisdiction have related their programs to the Agreement more than others. In some states, the last revision made to their standards preceeded the 1978 Agreement and therefore do not reflect those objectives. The revisions now under consideration will recognize the Agreement and the objectives to a greater extent.

One of the major programs established by the Agreement is the control of phosphorus to minimize eutrophication problems and to prevent degradation resulting from discharges of phosphorus to the lake system. Annex 3 of the Agreement deals with the control of phosphorus. Among other provisions, the Annex establishes phosphorus loads for the base year (1976) and future phosphorus loads. It calls for the Parties, in cooperation with the State and Provincial Governments, to confirm the future phosphorus loads and establish load allocations and compliance schedules within 18 months after the Agreement is signed. This date was passed last May and the Parties have not yet established the load allocations as required. However, extensive discussions are being carried out between the two countries on this matter.

Another important requirement in this section on phosphorus control is that municipal waste treatment plants discharging more than 3,800 cu m/d (1.0 MGD) shall achieve effluent concentrations of 1.0 mg/L total phosphorus maximum for plants in the basins of Lakes Superior, Michigan and Huron and 0.5 mg/L total phosphorus maximum for plants in the basins of Lake Ontario and Lake Erie where necessary to meet the loading allocations or to meet local conditions whichever are more stringent.

The Annex also calls for a reduction of phosphorus in household detergents to 0.5 percent by weight where necessary to meet the loading allocations or to meet local conditions whichever are more stringent. All the Great Lakes states except Ohio, Pennsylvania and Illinois have now instituted bans on phosphorus in detergents. In Ohio and Illinois, the Cities of Akron and Chicago, respectively, have limited the phosphorus in detergents.

The Agreement establishes two additional deadlines which will have an effect on programs in the U.S. Article VI calls for programs for municipal sewage treatment facilities to be completed and in operation no later than December 31, 1982. Programs for the abatement, control and prevention of pollution from industrial sources are to be completed and in operation no later than December 31, 1983.

Based on this brief review of some of the Great Lakes Water Quality Agreement requirements, one can conclude that the Agreement has had a decided impact on policy and programs in the United States portion of the Basin and will continue to do so. The Agreement has been a positive factor in cleaning up the Great Lakes. We have not yet reached the point where we can sit back and congratulate ourselves on completing the restoration and enhancement of the water quality in the Great Lakes System. However, we are making progress and every effort, including the output from seminars such as the one we are participating in here, moves us a little further down the road towards our goal of an improved Great Lakes System.

State/EPA Agreements: A State/Federal Partnership

by David Stringham

Getting the EPA Region V Office and its State counterparts to agree on priority environmental problems and ways to solve them is the objective of our new planning process--the State/EPA Agreements. The goals of the Agreement planning process are: (1) to make the Federal and State governments partners in determining priorities for State and Federal funding assistance and technical assistance; (2) to bring important environmental problems to the attention of senior management at both the Federal and State agencies; and (3) to surface environmental problems that might not be covered by any individual environmental program and that may demand a creative mixing of funds from a number of programs. In addition, we expect the Agreements, properly drafted in understandable English, to be an important vehicle for communicating the direction of EPA and State programs to the public.

The Agreements influence how environmental problems are addressed because they have a direct bearing on how EPA and the States allocate millions of dollars to various aspects of their environmental programs. The major programs included in this year's State/EPA Agreements cover a range of activities authorized by Federal statutes, including The Clean Water Act, The Safe Drinking Water Act, The Clean Air Act, The Resource Conservation and Recovery Act, and The Toxic Substances Control Act.

For the 1980 fiscal year, our first full year with this process, Agreements have been completed in all six Midwest States. Implementation of SEA provisions, while admittedly mixed, is generally proceeding. Development of the FY 81 Agreements began late last winter. The process begins with each State and Region V developing their own list of environmental problems and priorities, air quality, water quality, and solid and hazardous waste are all considered. And though there are many different kinds of problems in each, the Agreement process usually identifies a total of only a dozen or so of the most important issues for special attention. These issues range from concern over a particular type of pollutant to concern about a particular stretch of river. The lack of pretreatment for industrial wastewater or the need for programs to control pollution caused by farming practices are examples. In addition, the Agreements note significant program operation problems, such as State/EPA work sharing or delegations oversight, needing special study.

Once EPA and the States develop lists of these issues independently, they meet to resolve differences. The next step then is to work out the general solutions for each issue. The solutions usually relate to improved implementation of EPA and State environmental protection programs.

In FY 1980 only one State in Region V, Michigan, had a specific Great Lakes issue in its SEA and received Great Lakes funding to conduct Great Lakes surveillance. This activity included: nearshore studies on Lake St. Claire, Thunder Bay, St. Ignace and Cheboygan; Great Lakes loading flow analysis and water intake studies; and a salmon residue monitoring program.

FY 1981 will see three States (Michigan, Indiana and Ohio) with Great Lakes SEA issues. An additional State, New York, may also develop a Great Lakes SEA highlight in connection with a special regulatory assessment and broad scale intensive survey of the Niagara River in New York. Both the draft Indiana and Ohio State EPA Agreements focus attention on special problems in nearshore areas of the Great Lakes--estuaries, harbors and beaches which are seriously degraded due to combinations of point and nonpoint pollution. These degraded waters, while small in relationship to the total lake system, are a portion of the Great Lakes seen and used by millions of people. The municipal, industrial and storm runoff loading concentrated in these areas and some upstream urban industrial areas impact both local use and the lakes as a whole and are a logical focus for control efforts.

Industry has been required to expend large amounts of money for waste treatment in these nearshore areas. Also, large amounts of local, State and Federal funds have been expended in constructing municipal treatment works, and far more funding is being planned for both treatment works and control of combined sewer systems. Additionally, programs for the control of urban storm runoff are being developed in an attempt to deal with pollutants in urban storm water. These efforts in the past have been oriented toward conventional pollutant control, but our activity under the SEA Agreements will also heavily emphasize control of toxic pollutants.

The benefit of these past efforts, in terms of impact on estuary and nearshore areas, is not well known. Conversely, it frequently is not known what controls are needed to reach various levels of ambient water quality. These problems exist elsewhere on river systems but are less critical than in harbor and estuary localities. Because of the hydrologic complexity of estuaries, the Great Lakes relatively long retention time, and the intense use for water supply and recreation associated with these water bodies, information needs for regulatory efforts tend to be greater in these locations. At the same time, many of these areas have already received extensive investigation, making considerable regulatory progress possible.

The focus of our initiative in the Ohio and Indiana SEA's will be in the vicinity of the Urban/Industrial Gary-Indiana Harbor and the Toledo, Greater Cleveland and Ashtabula areas. The specific goals of these Urban-Industrial elements of the Agreements are to control pollution in Lake Michigan and Lake Erie; to protect and enhance drinking water, recreation, commercial and aesthetic uses of these waters; and to slow the eutrophication processes in the Great Lakes.

Initial sections in these SEA's summarize these specific goals and spell out agreement on the priority problems as perceived by the public, the State, and the Federal government. These initial sections are followed by a so-called "Problem Solving Approach" (or PSA) that lays out the key steps for attaining the jointly perceived goals. In both the Ohio and Indiana Great Lakes elements the first step toward solving the problem is to be a joint State-Federal review of all available information about the problem area; and this may provide a basis for immediate implementation of remedial programs. This initial information base, can also serve as a basis for development of a pollution control strategy which, when combined with other activities to further define the extent and nature of the problems, will provide both the State and the Federal government with the basis for further remedial program efforts as needed.

Key steps in the supplementary assessment work will be fish flesh and sediment analysis for toxic contaminants, review of combined sewer overflow studies and the conditions around major storm sewer outfalls, location and evaluation of major nonpoint sources of pollution (such as pits, ponds, lagoons and landfills), and process assessment of relevant industrial dischargers. Other data to be reviewed will relate to drinking water taste and odor problems, swimming bans and beach closings, fish consumption warnings, incidents of gross pollution, recent performance of sewage treatment plants that discharge in these areas, and major industrial discharger permit compliance.

The final steps to address these Urban-Industrial Great Lakes issues focus on performance of needed regulatory actions. Among the actions expected in this phase of the joint effort may be the evaluation of existing pretreatment and/or sewer use ordinances as administered by local sewage treatment plants, designation of plan of study areas for development of regional sludge management plans, development of plans to accelerate sewage treatment plant improvements, preparation of a management plan for any in-place pollutants; development of pretreatment and permit revisions and identification of necessary enforcement actions.

In response to national priorities and in recognition of the particular environmental needs of the State of Ohio a second Great Lakes highlight element was negotiated to promote control of phosphorus in Lake Erie, where the natural ecosystem and the fishery supported by it have been disrupted by accelerated eutrophication. The discussion of phosphorus induced problems in the Agreement provides basis for the detailed objectives which are: (1) that Ohio's industrial dischargers attain maximum practicable reduction of phosphorus discharges to Lake Erie; (2) that Ohio's municipal dischargers attain effluent phosphorus limits of 1 mg/l for all plants discharging more than one million gallons per day, (3) that Ohio's detergent phosphate limits be reviewed in the light of Federal evaluation of OEPA cost-benefit data and any applicable resolutions of the U.S.-Canada Water Quality Board, and (4) control of agricultural nonpoint source pollution through implementation of agricultural best management practices.

The problem solving measures for this phosphorus control issue include review of and high priority attention on municipal and industrial phosphorus dischargers to assure early compliance and an effective follow-up strategy for permit violators, development of a method and schedule for periodic updating of the Great Lakes phosphorus compliance and municipal point source loading reports, and an exchange of critiques between OEPA and USEPA about OEPA phosphate detergent ban cost-benefit data. This Agreement includes a commitment from USEPA for financial support for two agricultural nonpoint source control projects on streams tributary to the western basin of Lake Erie, and a commitment from OEPA to participate in the activities of the U.S.-Canada Water Quality Board and the IJC Great Lakes Phosphorus Management Task Force.

The Michigan EPA Agreement will include two unique Great Lakes issues for the coming year. The first, named the Multimedia Monitoring Highlight, relates to the fact that additional data and monitoring needs required for dealing with toxic and hazardous materials will strain the State monitoring budget.

In an effort to more effectively utilize the limited State resources, the Michigan Department of Natural Resources and USEPA will coordinate and evaluate monitoring activities of all media in a selected problem area. The goal of this multimedia monitoring activity is not only improved monitoring efficiency, the State and USEPA also hope that the new monitoring initiative will provide a more complete environmental picture of a selected geographic area, so that a more balanced response will be available from environmental managers in remedying problems, and citizens affected by environmental problems might be given a better chance to appreciate the scope of the problems under consideration by environmental agencies.

The work elements associated with this highlight include identification of the geographic area for the study, a review of scheduled monitoring programs in the area, specification of monitoring or inspection data needed to identify interrelated air, water and solid waste pollution problems, development of a study plan, compilation of information from monitoring and study efforts, and identification air, water and solid waste pollution relationships. Preliminary conclusions and recommendations will be circulated among State and Federal program managers and the published report on the outcome of the monitoring study will be available to the public. A final work element in the PSA calls for development of remedial measures to correct identified environmental problems.

The second Great Lakes Highlight in the Michigan/EPA Agreement evolved from the recognition that open waters of the Great Lakes still receive unacceptable loadings of numerous pollutants and that some nearshore, estuary and bay areas in the State waters have been degraded with loss of beneficial uses due to intense loadings and limited dilutions. The Agreement proposes that concentrating efforts on these nearshore areas offers the opportunity to restore beneficial uses in these localities and to reduce major loadings which now enter the Great Lakes. The goal of the work effort is to develop an integrated management system for implementing planning, remedial and monitoring programs to protect the Michigan waters of the Great Lakes.

Key elements in the problem-solving approach are a definition of common water quality objectives; case study analyses of problem areas which have been successfully addressed, as well as those which presently do not meet the agreed upon objectives; and identification and definition of appropriate monitoring programs.

In all of these State/EPA Agreements specific tasks are assigned to the State and Federal partners, milestone schedules are established, and funding and responsible party assignments are settled. The FY 81 SEA documents have been under review by appropriate State and Federal agency personnel, as well as the public. Final revisions of the FY 81 draft documents are underway, and EPA expects that signing of these final documents by John McGuire, the EPA Regional Administrator, and the heads of the respective State environmental agencies will be completed by the first of October, the beginning the next fiscal year.

The purposes and uses of these State/EPA Agreements are ambitious. The Agreements are intended to be a decision document, a management tool, and a communications device. Their immediate purposes are to focus the attention of top officials on integrated program management, to identify high priority environmental issues, to guide the grants distribution process, to focus attention on tracking progress toward solving identified problems, and to inform the interested public and agencies. The implementation of the process will identify opportunities for useful reform in overall environmental program management. This, in turn, should result in the faster attainment of our environmental objectives and assure our goals for protection and improvement of our priceless heritage--The Great Lakes.

WATER QUALITY MANAGEMENT PLANS, STATUS, QUALITY, INTEGRATION AND IMPLEMENTATION

by

William G. Benjey*

Good morning. [As mentioned] I am Bill Benjey of the USEPA Ohio Water Quality Management Section. My purpose today is to give you an overview of the status and implementation of water quality management (WQM) plans. I would also like to discuss the need for emphasis on a balanced approach to point and nonpoint water pollution abatement. There are 220 WQM planning agencies nationwide and 37 within Region V, of which 194 nationally, and 33 within the Region, are at least conditionally approved, including the nonpoint pollution portions. Rather than regale you with statistics, I will restrict my observations to my perspective on Region V. The degree of specificity of WQM plans in identifying and addressing water quality problems is highly variable. In many cases point source based problems and recommended solutions are detailed (or discharge specific) relative to treatment of nonpoint sources (which are often generalized to the level of the State or a regional drainage basin comprising one-quarter to one-third of the State). The focus upon point sources of water pollution under the water quality management program dates from the designation of the original urban-industrial complex planning areas in 1974 and 1975. This is not too difficult to understand, given the legal priority then required for the immediate issuance of NPDES permits for point source dischargers, and the widespread public awareness of flagrant and dramatic examples of point source caused problems. Consequently, much of the emphasis of the water quality management plans now approved is upon point sources.

However, as you know, during the past three years the emphasis has shifted dramatically to nonpoint source pollution abatement planning and implementation, as reflected in the fact that section 208 funds can no longer be used for point source work. The rationale is that much of the initial point source planning work should be accomplished (although I will be the first to say much remains to be done), and that the benefits to be derived from reducing pollution from diffuse sources have been relatively ignored.

---

*Supervisory Environmental Protection Specialist, United States Environmental Protection Agency, Region V, Chicago, Illinois

We have arrived at a point where in general, point source problems are usually known and addressed with NPDES permits and/or the section 201 municipal construction grants programs; while most of the nonpoint problems are known only in gross terms (for example, estimates of sediment and phosphorus from the Maumee River to Lake Erie). There are exceptions to this rule, such as the remaining need for sound wasteload allocations and for implementation of industrial pretreatment to control point source effluent limitations. There are also a limited number of detailed nonpoint pollution control studies under the National Urban Runoff Program (NURP) and the testing of agricultural best management practices (BMPs) in special studies such as Black Creek in Indiana, Honey Creek in Ohio and the Red Clay Project in Wisconsin. However, the results are not in from the NURP projects, 6 of which are in Region V, and the Rural Clean Water Program (RCWP) and the new Agricultural Conservation Programs. There are 3 RCWP's in Region V, including Highland-Silver Lake, Illinois; Lower Manitowoc, Wisconsin; and Saline Valley, Michigan.

A coordinated and integrated approach to point source and nonpoint source related aspects of pollution problems in specific areas is one of the primary features missing from current WQM plans. We are all aware of the uneven and variable mix of water quality problems; urban, construction and agricultrual runoff, feedlots, malfunctioning septic tanks and package plants, and overloaded and inadequate municipal and industrial wastewater treatment facilities. Point sources are more easily addressed, but in many cases, a water quality problem has multiple causes. Consequently, focusing only on point sources will not guarantee attainment of the 1983 goals of the Clean Water Act, particularly when the parameters accumulate, such as phosphorus, heavy metals or toxic chemicals. It is at least highly embarrasing to build an elaborate treatment plant only to find that you have not significantly helped the problem. This is one reason for the AST/AWT reviews discussed earlier by Mr. Chaiken.

The lack of coordinated approaches can be remedied by taking all present pollution sources into account when devising geographic priorities for future study and implementation. Priorities recognize limited resources. By this time, priorities should also be highly area specific, that is, to the sub-basin level, and as problem specific as possible. In priority order, specific, tailored work plans for additional refinement of problem identification and implementation can be prepared for the sub-basins. Only in this manner will we be able to successfully approach the problems of each area. In any event, it is inefficient to attempt to implement structural or nonstructural abatement methods across the countryside regardless of the variable locations and magnitudes of the problems. In most cases more detailed work is needed to pin down the actual, as opposed to broadly defined "potential" problems.

The above process ought to be a part of an overall State strategy for addressing priority water quality problems. Often, States work upon strategies which include a section for point sources, and sections for agricultural nonpoint and urban nonpoint sources, etc. In addition, States have classified stream segments as effluent limited or water quality limited based upon whether or not advanced treatment of point source discharges is needed to meet water quality standards. All of these parts of the whole should be considered when setting forth specific priorities.

Making a joint priority system requires drawing together planning for programs which operate on vastly different funding and at different speeds. Obviously the municipal construction grants program has resources to move much more quickly than nonpoint pollution abatement. Yet, nonpoint "tradeoffs" are supposed to be considered in construction grants facilities planning. In order to set overall State priorities by sub-basins, any known characterization of nonpoint pollution problems in a given sub-basin could be made a part of the "severity of problem" and other factors of the municipal construction grants priority list prepared by the States. Alternatively, a separate ranking system could be established into which the municipal construction grant priorities feed. Because of the need for cooperation of various agencies (agricultural, health, etc,), it is advisable to have their input on the problems with which they are most familiar.

Region V states have or are developing Statewide agricultural strategies, often around the State sediment control laws, and groundwater strategies. Groundwater quality, of course, is affected by surface water pollution. Statewide problem area priorities are in different stages of development, with Wisconsin the most advanced at this time in this Region. However, they are not yet integrated strategies.

Current prototype nonpoint pollution projects are, of course, limited in geographic coverage. The question arises; how can we get effective nonpoint pollution abatement with so much area, and so little money available? Here again, a State strategy is important. The immediate reaction is often to propose additional Federal, State or local funding, or all of the above, usually as some variety of a cost-sharing program, such as in Wisconsin and Illinois. This is certainly a valid approach. However, we all know that the prospects of expanding limited sources of money from any level of government in the current economic situation is not good. Additional regulations may help in some circumstances. However, they too often prove unwhieldy as well as locally unwelcome in dealing with nonpoint problems. Most States have a sediment control law as a basis, in any event. Our next tactic must be to selectively work upon nonpoint problems in order of the degree of severity of the water pollution problem to which they contribute, in accordance also with overall sub-basin priorities. Even so, it is necessary to pool the resources of all State, Federal and local agencies, in order to concentrate upon specific, identified areas with water quality problems. For example, a water quality management plan may place a priority order upon sub-basins with water quality problems largely induced by agricultural runoff. In this event, USEPA, the U.S. Department of Agriculture and the State water quality and agricultural agencies should cooperate in focusing their water quality efforts and funds upon the sub-basins in priority sequence. Their actions must be in cooperation with each other and the local landowners through the designated management agency (often a soil and water conservation district). If septic tanks are a problem, a health department may be involved. There will usually be several actors involved.

The primary intermediate water quality problem objective which is heard incessantly is implementation, improved water quality of course being the final objective. Implementation requires more than just a concerted effort by agencies, as we all know. In agriculture, landowners and soil and water districts must see the specific water quality problem and the benefit of BMPs and cleaner water for themselves. In addition to demonstrating the general value of soil and nutrient retention, it is important to demonstrate the presence of problems and importance of water quality in a specific area, in order that water quality be made significant and tangible to landowners. Cities and counties must see the importance of clean and abundant water in relationship to their current and future needs in water supply and recreation. This again ties in with the need to concentrate on specific, known, high priority problem areas. It is also increasingly important that the State and areawide water quality agencies provide necessary data to the designated management agencies to assist and document implementation of BMPs and the effects on water quality. This represents a change in role from the initial days of water quality planning, when local agencies provided information to State and areawide agencies to demonstrate perceived problems.

I have mentioned five items which are complementary approaches to water quality abatement. They are: (1) following integrated sub-basin priorities, (2) interagency cooperation, (3) costsharing, (4) regulation and (5) provision of more direct information and assistance to specific implementing agencies. These items should all be parts of State strategies. The strategies should result in concerted efforts in selected areas and more effective and demonstrable results in terms of water quality.

WATER QUALITY STANDARDS

by Michael MacMullen

Water Quality Standards consist of two general parts: (1) biological uses to be protected, and (2) specification of criteria necessary to attain the designated use. Standards are enforceable through NPDES permits.

Section 101 of the Water Pollution Control Act Amendments (P.L. 95-217) establishes a national water quality goal for accomplishment wherever attainable (emphasis supplied) of a water quality providing for the protection and propagation of fish, shellfish, and wildlife, and also providing for recreation in and on the water by July 1, 1983. It is precisely this aspect of attainability, however, which has not been dealt with in a systematic manner up until the present time. Henceforth, water quality standards activities will be conducted through the focus of prioritized attainability analyses.[1]

Under the new focus of attainability analyses, the principal emphasis of the water quality standards activities will be shifted from the three-year review/adoption cycle previously utilized, to one year standards program plans designed to provide the necessary water quality, technologic and socioeconomic data necessary to make sound decisions. In EPA-Region V, the priorities for acquisition of the necessary attainability information will be negotiated between the individual States and appropriate Regional Office staff in consideration of the need to reissue major permits and to make supportable decisions regarding the level of treatment beyond secondary which may be needed by municipal sewage treatment facilities. Results of the negotiations will be confirmed in the State/EPA Agreements.

Pending acquisition of attainability information in accord with the prioritized schedule, EPA will not require upgrading of any Water Quality Standard to the level specified in Section 101. Similarly EPA will not approve of downgrading actions without the necessary attainability information. NPDES effluent limitations would be set at levels consistent with operation of existing treatment facilities or application of categorical effluent limitations, whichever is more restrictive, prior to completion of attainability analyses for the receiving water in question. Following completion of the attainability analysis, the NPDES permit limitations will be set at whatever level is necessary to achieve compliance with the attainable Water Quality Standard.

EFFECTS OF POLLUTANTS ON HUMAN HEALTH

Leland J. McCabe
Health Effects Research Laboratory
Cincinnati, Ohio 45268

The EPA's two health effects laboratories conduct research to provide data for standards setting purposes. These data and the results of other research are used by the Office of Health and Environmental Assessment in Washington to provide risk assessments for the regulatory programs. In some cases there is a close working relationship between the laboratory and the regulatory program and information is provided directly on a continuing basis. In my experience this has been true in the drinking water program. But interaction between the research laboratories and the regulatory programs is being enhanced by the Research Committee structure. The Regional Offices have a more reciprocal method of making these research needs known in the Research Committees.

The HERL in North Carolina has specialized in air pollution and the HERL in Ohio on water problems, but not exclusively, and there are smaller programs on other environmental problems at each laboratory. The majority of our research in Cincinnati is concerned with drinking water, but I will review these activities that may be more germane to point vs. diffuse source pollution.

Bathing Beaches

The Agency has a criteria for recreation water quality in the Red Book (1) of a mean of 200 fecal coliforms per decaliter. The bases for the criteria were a series of studies conducted in the early 1950's and were from data on freshwater with considerable extrapulation. For the past eight years we have conducted microbiological methods research and a series of epidemiological studies at saltwater beaches. This illustrates that research on health effects does not provide fast answers to complex problems.

The concept was to develop a relationship between water quality and illness experienced by swimmers. A decision could then be made on acceptable risk of illness and from the relationship the necessary water quality would be determined. A report on these marine studies has been completed (2) and the figure shows tHe relationship.

The study design called for measurement of water quality by as many methods as possible, including currently used methods, and then seeing which water quality parameter best correlated with illness related to sewage, fecal pollution. Both pathogens and indicator organisms were considered and a series of facile methods developed.

For presentation September 16, 1980. Seminar on Water Quality Management Trade-Offs, Chicago, Illinois

The epidemiological protocol developed used a more rigorous definition of exposure than had been used in past studies; the head had to go into the water. The study areas were selected to provide a beach with "barely acceptable" water quality--that is, a beach not posted as "Swimming Not Allowed", and a beach that was relatively unpolluted. The beach user population also had to be large enough to provide an adequate study population. Families were interviewed at the beach on Saturday and Sunday as to exposure and then called on Monday, 9 to 10 days later to obtain information on additional midweek swimming and illness experienced during the week following the exposure trial being studied. The statistic used was the illness difference between swimmers and nonswimmers and thus control was achieved over the many other factors that could affect illness rates. Adjustments were made on the demographic variables of age, sex, race, and socioeconomic status.

The figure shows the relationship develop for the illness defined as highly credible gastrointestinal symptoms. That is an illness syndrome involving vomiting or diarrhea with a fever or disabling enough for an individual to remain home, remain in bed or seek medical advice, or stomachache or nausea accompanied by a fever. Data points from three areas were combined for this graph; New York City, Lake Pontchartrain, Louisiana, and Boston Harbor. Some confirmatory information was also obtained from an Alexandria, Egypt study.

The best indicator to fit the illness data was the Enterococcus density as measured by a method developed in the study (3). For an increased illness rate of 1 percent, the Enterococcus density would be 13.6 per decaliter and for 5 percent increased illness, 906 per 100 ml.

A generalization of the data from the New York City beaches would equate 30 Enterococcus to about 200 fecal coliform with an increased illness rate of 1.8 percent.

Studies of the freshwater relationship were continued this summer in Oklahoma and at Lake Erie beaches. We would like to find a beach to study nonpoint source pollution.

Aerosols

Another problem area we were asked to study was the health effects of siting of sewage treatment plants. Region 5 asked us to determine if health effects could be demonstrated in persons living near a sewage treatment plant so a decision could be made about the necessity of aerosol suppressive devices at the O'Hare plant. Construction was allowed to continue if research would provide data for evaluation before the plant went on line.

Fortunately, we had some research underway on the health of sewer workers and additional projects were started and completed within the 3 1/2 years provided. A symposium was held at Cincinnati in September

1979 where study results were presented and discussed. The report on the symposium is at the printers (4). We participated in writing the final environmental impact statement for the O'Hare plant and it started operation in May of this year.

I am not completely satisfied that we developed adequate methodologies for the studies, but our assessment was that despite the fact that some microorganisms are emitted by aeration basins of a sewage treatment plant, there is no detectable increase of disease in persons exposed to the aerosols. This is true not only with persons living or going to school near a treatment plant, but also with sewage treatment plant workers who normally have a higher exposure than the nearby residents.

As we have in the bathing water studies, it is reassuring to have a dose response relationship that can be then extrapolated back to a no effect level or acceptable effect level. This was not possible in the aerosol studies because adequate numbers of new sewage treatment workers, exposed before immunities had developed, could not be studied and our serological epidemiological techniques could not focus on the correct etiological agents.

Toxic Effluents

When the Agency finally got serious about providing the Criteria Documents in the spring of 1978 our laboratory was given three months to produce the human health effects portion of 20 of the 65 consent decree documents. We met our deadline and the criteria were published for review in the Federal Register (5). The final documents are expected to be available this month. This illustrates that assessment of current knowlege on health effects can be made quickly at any time, but may lead to protracted controversy in the review process.

Our own research, both inhouse and extramural, contributed more heavily to the chloroform and asbestos documents. The Environmental Criteria and Assessment Offce in Cincinnati is now in charge of producing the documents, but members of our laboratory staff have continued to serve as many of the committees developing the total set of criteria documents.

Most critical to the Great Lakes will be the toxic pollutants that have significant bioaccumulation. The methodology has been changed from that used in the review documents. Previously the weekly consumption was assumed to be 18.7 grams of edible aquatic products. This estimated consumption has been reduced to include only freshwater and coastal fish/shellfish and many of the bioaccumulation factors have been revised. In 38 of the review documents the intake from both water and fish was considered. In 15 (39%) the fish intake dominated, in 22 (58%) the water intake dominated, and in one case the impact was equal. The final documents should be reviewed to see where the fish intake dominates or makes a significant contribution. Because of the Great Lakes fishery resource such toxic pollutants will require the most close surveillance. There will also be populations where the average fish consumption is greatly exceeded and their health studies should be evaluated.

In several cases limits could not be set for some of the consent decree chemicals. The table lists the six chemical for which it was not possible to set limits because the health effects data base was inadequate. For 13 other chemicals the limit was set only on organoleptic effects, taste or odor, and no health effect limit was set. In two additional cases both a organoleptic and health effects limit was considered for review. Our laboratory is conducting research to fill the data gaps at the projected rate of 10 chemicals per year. New chemicals are, of course, developed at a faster rate but our research on testing methodology should assist in covering this problem by premarket testing under the Toxic Substances Control Act.

References

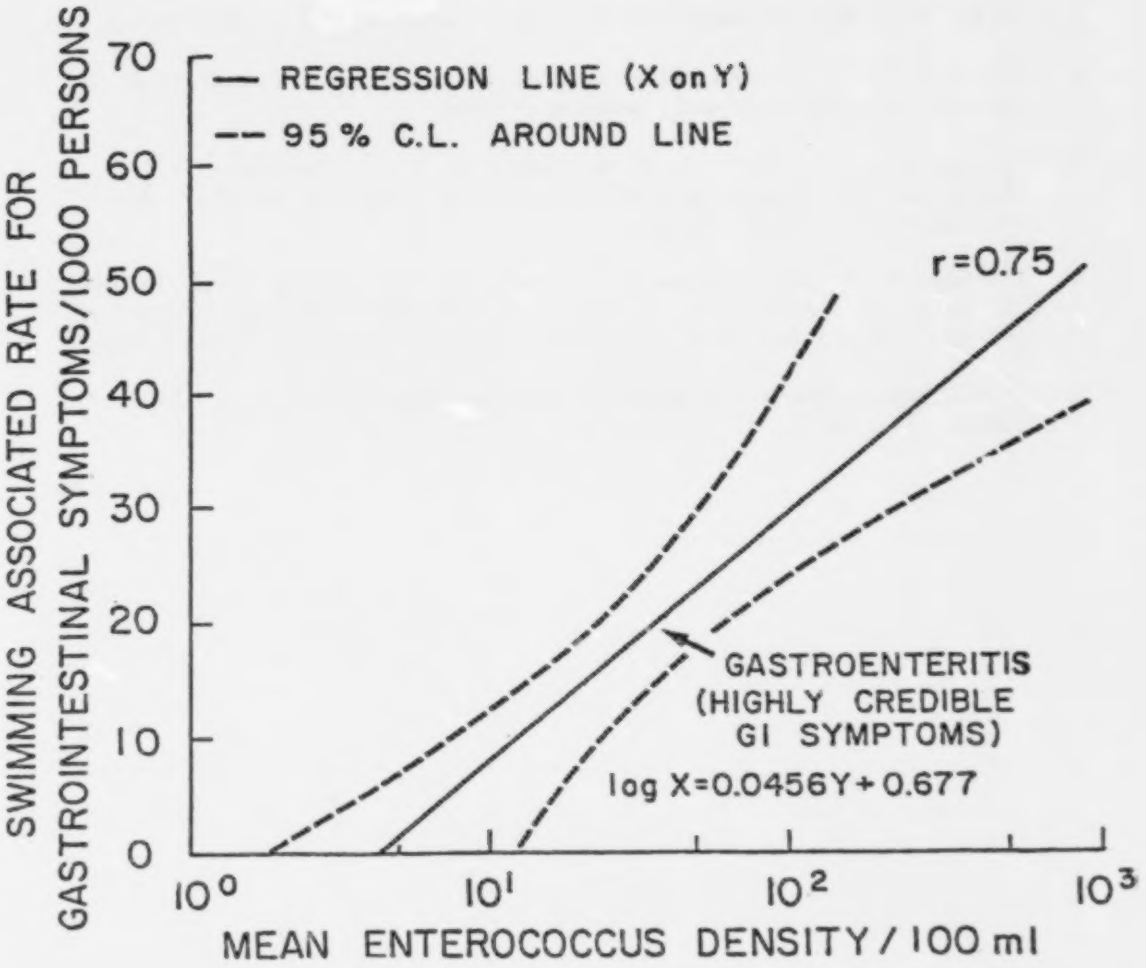
1. U.S.E.P.A. Quality Criteria for Water, Washington, D. C. (1976).

2. Cabelli, V. J. Health Effects Criteria for Marine Recreational Water. EPA-600/1-80-031, September 1980.

3. Levin, M. A. Fischer, J. R. and Cabelli, V. J. Membrane Filter Technique for Enumeration of Enterococci in Marine Waters. Appl. Microbiology, 30:66 (1975).

4. Pahren, H. R. and Jakubowski, W. (eds.). Wastewater Aerosols and Disease. Proceedings of a Symposium, EPA 600/9-80-028, U.S.E.P.A. Health Effects Research Laboratory, Cincinnati, Ohio, June 1980.

5. E.P.A. Water Quality Criteria. Federal Register 40 (52) 15926 (March 15, 1979).



Recommended Health Effects Criterion
for
Marine Recreational Waters

CONSENT DECREE POLLUTANTS

Could not set health limit.

- 2,4-dimethylphenol
- Chlorocresol (Chlorinated Phenols)
- Haloethers
  - Chlorophenyl phenyl ethers
  - Bromophenyl phenyl ethers
  - Polychlorinated diphenyl ethers
- 2,6-dinitrotoluene

Criteria based on organoleptic effects.

Copper	1	mg/l	
Zinc	5	mg/l	
Acenaphthene	0.02	mg/l	
Hexachlorcylopentadiene	1.0	μg/l	
Nitrobenzene	0.03	mg/l	
Chlorinated Phenols			
a) Monochlorophenols			
2-chlorophenol	0.3	μg/l	
3-chlorophenol	50	μg/l	
4-chlorophenol	30	μg/l	
b) Dichlorophenols			
2,4-dichlorophenol	0.5	μg/l	371 μg/l H.E.
2,5-dichlorophenol	3.0	μg/l	
2,6-dichlorophenol	3.0	μg/l	
c) Trichlorophenols			
2,4,5-trichlorophenol	10	μg/l	
2,4,6-trichlorophenol	100	μg/l	
Chlorinated benzenes			
Monochlorobenzene	20	μg/l	450 μg/l H.E.
Trichlorobenzene	13	μg/l	

SOURCES OF POLLUTANTS TO THE GREAT LAKES

by

W. Ronald Drynan*

Pollutants are introduced to the Great Lakes principally through municipal and industrial point source wastewater discharges, atmospheric deposition, and urban and agricultural land runoff. In the lower Great Lakes, interlake transfer via the connecting channels can also be a significant source of contaminants. The relative importance of each source, in terms of its contribution to the total load of a given pollutant, varies depending upon the specific lake and pollutant under consideration.

The point sources being relatively easy to locate, sample, and obtain flow measurements for are generally more adequately monitored than nonpoint sources. The diffuse nature of nonpoint sources make them extremely difficult to monitor and the fact that any pollutant loads transported to the lakes are influenced by highly variable hydrologic and atmospheric phenomena make it difficult to estimate annual loadings and discern changes from year to year.

Pollutants can be generally classified in five groups: oxygen demanding substances, suspended solids, nutrients, trace metals, and toxic organic substances. The classical parameters, BOD and suspended solids, used to measure the strength of domestic sewage, and estimate the impact of wastewater discharges on dissolved oxygen and sedimentation problems in estuaries and tributaries, have relatively little significance in terms of the Great Lakes.

Many of the water quality problems of the Great Lakes have been associated with eutrophication with phosphorus being implicated as the major nutrient contributing to eutrophication. Concern of the deteriorating water quality of the lakes and the need for joint efforts to restore and enhance them led, in 1972, to the signing of the Great Lakes Water Quality Agreement between Canada and the United States. A major focus of the Agreement was on programs to reduce the total loadings of phosphorus to the lakes. The most complete information on the total annual loadings of any pollutant to the lakes and their sources is available for phosphorus.

In the late 1960's point source discharges, particularly municipal wastewater, were identified as the major sources of phosphorus loadings. Programs to reduce phosphorus loadings have been directed primarily at the municipal sources. As these programs, primarily chemical precipitation of phosphorus at municipal sewage treatment plants, have been implemented nonpoint sources have become an increasingly significant

---

*Senior Engineer, International Joint Commission, Great Lakes Regional Office, 100 Ouellette Avenue, Windsor, Ontario N9A 6T3

proportion of the total residual loads. Table 1 shows the present phosphorus loadings to each lake from the various sources. Current analysis indicates that achievement of desirable water quality conditions in Lakes Erie and Ontario will require further reductions in total phosphorus loadings which can only be achieved by implementing controls in both point and nonpoint sources (1).

TABLE 1

TOTAL PHOSPHORUS LOADS TO THE GREAT LAKES (1976)
(metric tons per year)

Lake	Direct Municipal	Direct Industrial	Tributary Total	Tributary (Diffuse*)	Atmosphere	Urban Direct	Upstream Load	Total
SUPERIOR	72	103	2,455	(2,222)	1,566	16	-	4,212
MICHIGAN	1,041	38	3,596	(1,891)	1,682	-	-	6,357
HURON	126	38	2,901	(2,428)	1,129	16	657	4,867
ERIE	6,292	275	9,960	(8,718)	774	44	1,080	18,425
ONTARIO	2,093	82	4,047	(3,257)	488	324	4,769	11,803

* Tributary loads minus estimates of point source loads discharged upstream to the tributaries

Sources - Final Reports of Pollution from Land Use Activities Reference Group(2) and the Phosphorus Management Strategies Task Force Final Report(1)

In recent years, water quality concerns have shifted to problems associated with heavy metals, such as lead and mercury, and toxic organic substances. The methylation of mercury discharged to the lakes and its subsequent bioaccumulation to levels of concern in fish and the possibility that discharges of other metals, such as lead, may lead to similar problems has focussed interest on the sources of these contaminants. Identification of significant levels of toxic organic substances, such as PCB, DDT and mirex, in fish and herring gulls has also created an interest in determining the sources of these contaminants to the lakes. The information available on sources of these micro contaminants is very incomplete and any assessment of the relative importance of possible sources is much more speculative than for conventional pollutants such as phosphorus.

POINT SOURCES

Information on point source dischargers to the Great Lakes is maintained in an "Inventory of Major Municipal and Industrial Dischargers in the Great Lakes Basin"(3) and reported annually to the IJC by the Great Lakes Water Quality Board. An annual estimate is made of the flow and total loads of BOD, suspended solids, and total phosphorus discharged by municipal point sources discharging more than 3,800 cu m/d (1MGD) and all those discharging directly to the lakes. Most other parameters of concern are not measured routinely at municipal wastewater treatment plants and in any case data on these are not routinely reported to the IJC.

The U.S. EPA is presently funding a survey of some 50 cities in an effort to evaluate the extent of the 129 priority pollutants in wastewater entering municipal wastewater treatment plants, their sources, removal efficiencies, and amounts accumulating in sludges. Preliminary information indicates nine of the thirteen heavy metals (Cd, Cr, Cu, Pb, Mn, Hg, M, Ag, and Zn) and six organic pollutants (benzene, chloroform, methylene chloride, bis (2 ethylexyl) phthalate, tetrachloroethylene, and toluene) were found in nearly all wastewaters.

Estimates of the amounts of four heavy metals (Pb, Zn, Cu, and Cd) discharged to the Great Lakes via municipal wastewater, based on the levels detected in treated effluents and the total flow from treatment plants(1), are shown in Table 2.

TABLE 2

MUNICIPAL DISCHARGES OF TRACE METALS TO THE GREAT LAKES*
(metric tons per year)

	LAKE				
Metal	Superior	Michigan	Huron	Erie	Ontario
Zn	7.9	103.0	23.9	228.2	146.3
Pb	1.8	22.9	5.3	50.7	32.5
Cu	1.8	22.9	5.3	50.7	32.5
Cd	0.5	6.9	1.6	15.2	9.8

* Based on 1978 reported municipal wastewater discharge(3) and the following assumed effluent concentrations in municipal wastewater discharged: Zn - 90 ug/L, Pb - 20 ug/L, Cu - 20 ug/L, and Cd - 5 ug/L.

The present criterion for reporting industrial pollutant loading information, other than total phosphorus, to the IJC is based on a determination by each jurisdiction of those parameters which may be of significance to the Great Lakes. A great deal of self-monitoring and compliance monitoring by regulatory agencies is carried out for industrial discharges to satisfy U.S. NPDES and the Ontario Ministry of the Environment industrial waste control monitoring requirements. However, these data are not all reported nor analyzed in any comprehensive manner to obtain total industrial loading of any pollutants. Reported industrial inputs of the four heavy metals (Zn, Pb, Cu and Cd) are shown in Table 3 based on the information reported in the 1978 "Inventory of Major Municipal and Industrial Point Source Dischargers in the Great Lakes Basin"(3).

TABLE 3

INDUSTRIAL DISCHARGES OF TRACE METALS TO THE GREAT LAKES*
(metric tons per year)

	LAKE				
Metal	Superior	Michigan	Huron	Erie	Ontario
Zn	10.2	50.0	32.5	148.6	64.4
Pb	-	0.6	-	38.2	7.8
Cu	1.0	9.7	11.0	43.4	15.5
Cd	-	0.02	-	0.3	1.8

* Reported by Great Lakes Water Quality Board in 1978.([3])

An additional point source, for which little or no information is currently available, is combined sewer overflows. These highly variable discharges are difficult to sample and obtain flow measurements in order to make estimates of the total quantities of pollutants they introduce into the lakes. In some of the major metropolitan areas, such as Detroit and Cleveland, with combined sewers these discharges may be significant, particularly in terms of local water quality impacts. Their impact on total pollutant loadings and whole lake water quality remain to be determined.

NONPOINT SOURCES

Estimates of nonpoint source pollutant loadings to the lakes are based on measurements of flow and pollutant concentrations in samples taken at the mouths of major tributaries to the Great Lakes.(4,5,6) Estimates of annual pollutant loadings transported by tributaries are difficult to make due to the variability of the flows and pollutant concentrations throughout the year. Determining the relative contribution of various land use activities to the pollutant load carried by the tributaries is complicated by questions of delivery to streams, transport in streams and effect of the upstream point source discharges.

The most extensive attempt to assess the relative contributions of urban and agricultural runoff, and streambank erosion, and other land use activities to the total pollutant loads to the Great Lakes was the IJC's International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG). The PLUARG Final Report(2) and the technical report series(7) provide a great deal of information on types of pollutants and unit area loads from specific land use activities in specific locations throughout the basin. Using an Overview Model,(8) PLUARG extrapolated this information for phosphorus to estimate whole-lake loadings from land drainage. The overview model is presently being developed by the Great Lakes Basin Commission to make estimates of other parameters.(9)

Runoff from agricultural land, particularly erosion from row crop production on fine-textured soils, was identified as a major contributor of phosphorus to the Great Lakes. Urban and rural runoffs were also identified as possibly significant contributors of other contaminants. However, very little data are available upon which to make any estimates of the amounts of toxic organics or heavy metals which may be transmitted to the lakes from these sources.

Shoreline erosion is another nonpoint source which potentially contributes a large amount of pollutants to the lakes. Estimates of the total sediment and total phosphorus loads from shoreline erosion in each lake are given in Table 4. The whole lake impact of these loadings is considered to be quite minimal in that the phosphorus and other pollutants are not considered to be biologically available and are generally associated with larger particles which settle in nearshore areas. In any event, shoreline erosion has been occuring in the Great Lakes since their creation and any efforts by man to control the phenomenon would not likely result in reductions in pollution of the lakes commensurate with the expenditure of funds required for any significant control of shoreline erosion.

TABLE 4

SHORELINE EROSION AS A SOURCE OF SEDIMENT AND TOTAL PHOSPHORUS LOADINGS TO THE GREAT LAKES

(metric tons per year)

Lake	Tributary (suspended solids)	Shoreline Erosion (total sediment)	Total Phosphorus Shoreline[2] Erosion	1976 Total Phosphorus All Other Sources
Superior	1,378,260	11,279,000	3,800 [1]	4,212
Michigan	706,540	21,778,000	3,700	6,357
Huron	1,052,960	1,763,000	794	4,867
Erie	6,531,800	11,131,000	10,536 [3]	18,425
Ontario	1,597,000	3,206,000	1,280	11,803

Notes:
1. U.S. load only
2. PLUARG reports on U.S. and Canadian shoreline erosion.[3]
3. Canadian estimate for short term used (1972-1973) @ 9512 t/yr - Canadian long term estimates (1953-1973) @ 5912 t/yr.

ATMOSPHERIC SOURCES

Preliminary work carried out during the Upper Lakes Reference Group(10) and PLUARG Studies(11) indicated that atmospheric inputs may be a significant source of pollutants to the lakes particularly for toxic organics and some heavy metals. Work has continued in the difficult task of measuring dry and wet deposition and estimating annual atmospheric loads. Recently, contracts funded by the IJC's Great Lakes Science Advisory Board(12,13) summarized the available information on atmospheric inputs of organic and inorganic constituents to the lakes. These data are summarized in Tables 5, 6 and 7 for the nutrients and major elements, trace metals, and trace organics, respectively. While much of the data are preliminary in nature, and the sampling methodology and analytical techniques are still in early stages of development, the data indicate that the atmospheric pathway is a very significant input for total loads for parameters such as PCBs and lead, and it may be significant for some of the other organics, total phosphorus, aluminum, cadmium, copper, chromium, iron and nickel. For example, available data of loadings of lead from the various sources, as summarized in Table 8, indicate the dominance of atmospheric inputs for that parameter.

TABLE 5

TOTAL DEPOSITION OF AIRBORNE NUTRIENTS AND MAJOR ELEMENTS TO THE GREAT LAKES

(metric tons per year)

	LAKE				
Element	Superior	Michigan	Huron	Erie	Ontario
SO_4	205,000	259,000	179,000	113,000	85,300
NO_3/NO_2	41,000	46,000	41,700	25,100	19,000
Ca	#	173,000	#	50,200	28,400
Na	32,800	28,800	17,900	12,600	19,000
Cl	41,000	#	29,800	20,100	9,480
K	24,600	11,500	17,900	12,600	3,790
Mg	16,400	28,800	11,900	12,600	7,580
Si	24,600	11,500	11,900	7,540	948
Total Phosphorus	#	#	1,190	754	379

# Estimate not possible from available data.

TABLE 6

TOTAL DEPOSITION OF AIRBORNE TRACE METALS TO THE GREAT LAKES

(metric tons per year)

	LAKE				
Metal	Superior	Michigan	Huron	Erie	Ontario
Zn	8,210	#	#	#	948
Pb	1,230	1,730	596	754	379
Cu	821	575	298	151	95
Cd	82	58	60	75	28
Ni	328	575	89	75	76
Fe	8,210	#	4,770	3,270	1,520
Al	14,000	28,800	#	#	#
Mn	1,640	1,150	#	#	#

# Estimate not possible from available data.

TABLE 7

TOTAL DEPOSITION OF AIRBORNE TRACE ORGANICS TO THE GREAT LAKES

(metric tons per year)

	LAKE				
Compound	Superior	Michigan	Huron	Erie	Ontario
TOTAL PCB	9.8	6.9	7.2	3.1	2.3
TOTAL DDT	0.58	0.40	0.43	0.19	0.14
α-BHC	3.3	2.3	2.4	1.1	0.77
γ-BHC	15.9	11.2	11.6	5.0	3.7
DIELDRIN	0.54	0.38	0.55	0.17	0.13
HCB	1.7	1.2	1.2	0.53	0.39
p,p'-METHOXYCHLOR	8.3	5.9	6.1	2.6	1.9
α-ENDOLSULFAN	7.9	5.6	5.8	2.5	1.8
β-ENDOSULFAN	8.0	5.6	5.8	2.5	1.9
TOTAL PAH	163	114	118	51	38
ANTHRACENE	4.8	3.4	3.5	1.5	1.1
PHENANTHRENE	4.8	3.4	3.5	1.5	1.1
PYRENE	8.3	5.9	6.1	2.6	1.9
BENZ(a) ANTHRACENE	4.1	2.9	3.0	1.3	0.94
PERYLENE	4.8	3.3	3.4	1.5	1.1
BENZO(a) PYRENE	7.9	5.6	5.8	2.5	1.8
DBP	16	11	12	5.0	3.7
DEHP	16	11	12	5.0	3.7
TOTAL ORGANIC CARBON	2×10^5	1.4×10^5	1.5×10^5	$.66\times10^5$	$.46\times10^5$

TABLE 8

SOURCES OF LOADINGS OF LEAD TO THE GREAT LAKES
(metric tons per year)

Lake	Municipal	Industrial	Atmospheric
Superior	1.8	0	1,230
Michigan	22.9	0.6	1,730
Huron	5.3	0	596
Erie	50.7	38.2	754
Ontario	32.5	7.8	379

OTHER SOURCES

Several intermittent potential sources of pollutants to the Great Lakes, which are not well documented, include spills which occur during the transportation and handling of toxic or hazardous substances, dredging activities which may redistribute pollutants in sediments, disposal of dredged materials in open waters, and resource recovery operations such as drilling for gas in Lake Erie.

SUMMARY

The Great Lakes are subjected to pollutant loadings from a wide variety of sources. In the past, the major problems were attributed to municipal and industrial wastewater discharges of conventional pollutants. Concerns have now shifted to persistent, toxic substances that bioaccumulate, and find their way into the lakes via many different pathways and from as yet unidentified sources. While efforts need to continue to improve the estimates of total loadings of pollutants of concern such as phosphorus in order to provide direction for control programs, it is not practical to attempt complete mass balance input/output analysis for all pollutants, and particularly the toxic organics. It is important that the specific pollutants which are creating problems in the lakes be identified and efforts to identify various sources be directed at these. Methodologies are being developed to enable one to make first-cut estimates of the relative inputs of most pollutants from various sources. These efforts need to be continued since trying to monitor everything everywhere is not practical.

Improvements are needed in sampling and monitoring programs for both the tributary and atmospheric inputs. A coordinated program is required to identify atmospheric airborne contaminants and provide an adequate assessment of the loads from this pathway to compare with municipal and industrial and tributary loadings.

REFERENCES

1. Phosphorus Management for the Great Lakes - Final Report of the Phosphorus Management Strategies Task Force to the IJC's Great Lakes Water Quality Board and Great Lakes Science Advisory Board. Windsor, Ontario (July 1980)

2. Environmental Management Strategy for the Great Lakes System - Final Report of the Pollution from Land Use Activities Reference Group, Windsor, Ontario (July, 1978)

3. Inventory of Major Municipal and Industrial Point Source Dischargers in the Great Lakes Basin - Great Lakes Water Quality Board, Windsor, Ontario (July, 1979)

4. Annual Tributary Loadings - Great Lakes Water Quality Board Annual Report Appendix B, Windsor, Ontario (1975-1979)

5. United States Great Lakes Tributary Loadings - Pollution from Land Use Activities Reference Group, Windsor, Ontario (January, 1978)

6. Land Use, Water Quality and River-Mouth Loading: A Selective Overview for Southern Ontario - Pollution from Land Use Activities Reference Group, Windsor, Ontario (March, 1978)

7. Annotated Bibliography of PLUARG Reports - International Reference Group on Great Lakes Pollution from Land Use Activities - Windsor, Ontario (1979)

8. Management Information Base and Overview Modelling - M.G. Johnson, J.C. Comeau, T.M. Comeau, T.M. Heidtke, and W.C. Sonzogni - PLUARG Technical Report, Windsor, Ontario - August 1978.

9. U.S. Heavy Metal Loadings to the Great Lakes: Estimates of Point and Nonpoint Contributions - T.M. Heidtke, D.J. Scheflow, and W.C. Sonzogni, Great Lakes Basin Commission, GLEPS Contribution No. 12, Ann Arbor, Michigan (January 1980).

10. The Waters of Lake Huron and Lake Superior - Report to the International Joint Commission by the Upper Lakes Reference Group. 3 Vol. Windsor, Ontario. 1976.

11. Atmospheric Loadings to the Great Lakes - A Technical Note prepared for the International Reference Group on Pollution of the Great Lakes from Land Use Activities, IJC Great Lakes Regional Office, Windsor, Ontario (September, 1977)

12. Assessment of Airborne Inorganic Contaminants in the Great Lakes - Great Lakes Science Advisory Board, Windsor, Ontario (1980)

13. Assessment of Airborne Organic Contaminants in the Great Lakes - Great Lakes Science Advisory Board, Windsor, Ontario (1980)

TRIBUTARY LOADS AND EFFECTS

Summary of a Speech by Nelson A. Thomas on
"Biological Effects of Chloride and Sulfates on Lake Michigan"
September 16-17, 1980
Chicago, Illinois

Many of the Great Lakes water quality problems can be associated with the pollutant inputs from various tributary sources. Since the Great Lakes differ greatly in their trophic state, the impact of pollutants is highly varied and dependent upon type. Water quality problems can arise from sediment input; algal nutrient additions, such as phosphorus; heavy metals; and organic toxins, both industrial, agricultural. Many of the effects are related to each other because particulate matter carries much of the pollutant load to the lakes.

Sediment plays a vital role in the ecosystem of the lake. It has both deleterious and beneficial impacts. When present in sufficient quantities it blocks out the light to rooted aquatic plants, inhibits photosynthesis by phytoplankton, burys benthic animals, and covers fish spawning grounds. It may be beneficial in the sorption and removal of certain heavy metals and organic toxins. The sediments of the Great Lakes are the ultimate disposal sites of most of the persistent, non-conservative pollutants entering the Great Lakes.

It is important to quantify the effects of tributary inputs on the uses made in the Great Lakes. When determining the load reductions required, estimates can be made regarding the benefits to be derived from pollution control progams, when a cause and effect relationship can be established. To do this, it is important to: 1) know the magnitude of the input, 2) quantify the processes that reduce the pollutant, and 3) the relationship between pollutant concentration and water use. This approach has been used in the estimating of the target phosphorus loads cited in the 1978 Water Quality Agreement between the U.S. and Canada. Phosphorus loadings were related to taste and odor problems in Saginaw Bay, hypolimnic dissolved oxygen concentrations in Lake Erie, and the restoration of more desirable phytoplankton and zooplankton populations in Lake Ontario.

Nelson A. Thomas, Large Lakes Laboratory, USEPA, Grosse Ile, Michigan

LAND TREATMENT OF MUNICIPAL WASTEWATER

by

A. T. Wallace*

The topic suggested by the title, presented within the framework of this seminar on water quality management trade-offs, provides its author an interesting challenge. The seminar organizers correctly recognize that trade-offs may often be required and that decisions relating to water quality management cannot take place in a vacuum if any meaningful results are to be expected. Examination of point source control practices jointly, given a set of realistic objectives and a finite budget, is a logical, acceptable concept. Quite certainly it will prove to be in our best professional interests to have the tax-paying public understand at least the rudiments of this management approach.

Land treatment systems are only one subset of management tools which, under certain circumstances, can yield substantial water quality benefits with low capital expense and low O&M and energy commitments. However, utilization of this technology definitely involves consideration of trade-offs and often requires considerably more pre-design analysis than does the employment of conventional technologies. As land treatment technology frequently transforms a potential point source into a diffuse source, its discussion at this seminar seems especially apropos. Some materials pass through the soil, comingling with native groundwater; some are incorporated in growing plants which may be removed from the site. In some systems, such as overland flow (OF) or wet lands, contaminants may runoff to various collection or discharge points to again become point sources. Proper design and operation limits the percentage of applied contaminants which subsequently leave the site boundaries. Most importantly, a substantial mass of potential environmental pollutants are either permanently immobilized or transformed to less objectionable materials. I have insufficient time to expound on the technical aspects of land treatment. Also, there are a number of recent books and manuals which do an excellent job of this and some of these are listed in the references (4, 5). It should prove more worthwhile to discuss the topic philosophically.

THUMBNAIL HISTORY

We are speaking of ancient, rather than modern technology as most of you are aware. An EPA Water Program Operations Technical Report, "A History of Land Application as a Treatment Alternative", (1) provides clear insights into the reasons for the early acceptance, later rejection and current reemergence of the use of land treatment technology.

The impact of Federal legislation, beginning with PL 92-500 has been traced and analyzed by Thomas and Reed (2). Their review deals in particular detail with the Clean Water Act (CWA) of 1977 and subsequent EPA policy statements which carry a strong message that land treatment deserves serious consideration within the spectrum of wastewater management alternatives. Congress, as you may be aware, "loaded" the CWA with financial incentives for selecting "alternative" technologies, of which land treatment is the prominent example. Chief among these are:

---

*Professor of Civil Engineering, University of Idaho, Moscow, ID 83843

1. The federal share of a construction grant may be increased from 75% to 85%.
2. The federal government may participate with full grant funding in projects which are up to 15% more costly than the most cost-effective conventional alternative.
3. Projects which fail to meet design criteria are eligible for 100% federal grants for modification or replacement.
4. Land used as part of the treatment system is a grant eligible item and further, appreciates at a rate of 3% per year. (All other costs of course are calculated in constant dollars).

Evaluation of land treatment systems as a Best Practicable Waste Treatment Technology (BPWTT) in accordance with PL 92-500 requires that the groundwater quality criteria established by the Interim Primary Drinking Water Standards mandated by the Federal Safe Drinking Water Act, PL 93-523, be met. In addition, land treatment alternatives must be fully coordinated with on-going area-wide planning under section 208 of the Act. An October, 1977 memo from EPA Administrator Costle specified that section 208 agencies should be involved in the review and development of land treatment options.

LAND TREATMENT VS. CONVENTIONAL TREATMENT COMPARISONS AND TRADE-OFFS

The uniqueness of the design procedure for land application of wastewater affords an opportunity for far better control of most contaminants than does the utilization of conventional technology. In the design of conventional systems, one usually begins with the permit conditions and assembles, on paper, collections of sub-systems which can meet these objectives. The costs of qualifying systems are then estimated to see which meets the cost-effectiveness criteria of section 212(2)c of PL 92-500. This is the approach suggested in EPA's own guidance document (3). Obviously, this approach will produce systems which just meet the discharge limitations for the permitted parameters. Such systems may accomplish more or (generally) less removal of other parameters, not covered by the permit as written, for example the nutrients, nitrogen and phosphorus.

The design of land treatment systems on the other hand, proceeds by attempting to identify the land limiting constituent, which may include the liquid load (4, 5). Under this approach, better than minimal management of all other (foreseeable) contaminants is automatically assured. Of course this apparent advantage is not gained without some compensating disadvantages. Foremost among these is the sacrifice of the substantial dilution and dispersion mechanisms normally associated with surface water discharge. These are no longer available when contaminants reach flowing groundwaters via percolation. A related disadvantage concerns the impact of a temporary treatment dysfunction (fairly common for conventional technologies while rare, but possible, for land treatment). Similar problems may arise upon the arrival of an unusual "slug" of contaminant which cannot be attenuated to safe levels in passage through the system. In the case of conventional technology with end-of-pipe discharge, the impact upon the receiving water, although possibly severe, is usually temporary and rapid recovery is possible. Water intakes may be closed if the dangers warrant and ecological upsets are generally mitigated by natural repopulation from upstream or tributary sources. Planned restocking programs may be called for. In any event, the original water quality conditions can usually be restored in a fairly short time frame. Not so in the case of the land based treatment system. The relatively ineffective dilution and dispersion mechanisms, together with low velocities, permit the groundwater, once polluted, to remain so for a long while unless natural decay or adsorption mechanisms act to attenuate the contaminant(s).

Some other important differences are:

1. Land treatment systems can be designed for flows closer to average daily flow than conventional systems which generally require consideration of a peaking factor.

2. Provided that the necessary additional land is available, land treatment systems can be expanded much more easily and rapidly than most conventional systems (6).

3. Land treatment systems do not necessarily impose any significant aesthetic change on the receiving location, or require changes in existing land use. It may, for example, preserve agricultural or timber production, or a unique wildlife habitat. If technological changes should make all or a part of the system obsolete in future years, the site should have considerable salvage value (7).

CONCLUSION

Something worth remembering, and in fact the premise of an entire treatise on the subject (5) is that almost without regard for either the source and type of wastewater and the type of soil or site conditions, there is some safe loading which will control all contaminants and still not degrade the terrestrial receiver to the extent that any future uses are irrevocably precluded. It may be of course that this loading is too low to be economical and thus conventional technology provides a better solution. However, there have been many realistic exercises in comparative economics performed (5, 8, 9, 10, 11) and these tend to show substantial economic incentives for land treatment systems under a wide range of site conditions.

REFERENCES

1. Jewell, W. J. and B. L. Seabrook. June, 1978. A History of Land Application as a Treatment Alternative. U. S. Env. Prot. Agency 430/9-78. 83 p.

2. Thomas, R. E. and S. C. Reed. 1980. EPA Policy on Land Treatment and the Clean Water Act of 1977. J. Water Pollution Control. 52: 452-459.

3. Van Note, R. H. et al. July, 1975. A Guide to the Selection of Cost-Effective Wastewater Treatment Systems. Office of Water Programs Operations, U. S. Env. Prot. Agency 430/9-75-002.

4. Loehr, R. C., et al. 1979. Land Application of Wastes, Vols. I & II. Van Nostrand Reinhold Co. 739 p.

5. Overcash, M. R. and D. Pal. 1979. Design of Land Treatment Systems for Industrial Wastes - Theory and Practice. Ann Arbor Science Pub., Inc. 684 p.

6. Reed, S. C. and T. Buzzell. 1975. Land Treatment of Wastewaters for Rural Communities in Water Pollution Control in Low Density Areas. W. J. Jewell and R. Swan (Eds.) University Press of New England. p. 23-40.

7. McGowan, F. M. 1975. Water and Land Oriented Wastewater Treatment Systems in Water Pollution Control in Low Density Areas. W. J. Jewell and R. Swan (Eds.) University Press of New England. p. 3-14.

8. Jewell, W. J. 1979. Personal communication.

9. Reed, S. C. 1980. Personal communication.

10. Culp, G., Williams, R. and T. Lineck. Oct. 1978. Costs of Land Application Competitive with Conventional Systems. Water and Sewage Works 125:49-53.

11. Crites, R. W., Dean, M. J. and H. L. Selznick. Aug., Sept. 1979. Land Treatment vs. AWT - How Do They Compare? Water and Wastes Engineering 16:16-19, 51-53.

COSTS FOR WASTEWATER TREATMENT

by

James A. Hanlon

During the next few minutes this afternoon I would like to share with you some of the experiences we have gained over the last seven to eight years here in Region V in the construction grant program regarding the subject of the cost for wastewater treatment. As you might well by now recognize, the seven to eight year time span put us back generally to the point in time when the Federal Water Pollution Control Act of 1972 was passed by Congress in October of that year. As we all know it was that statue, public law 92-500, that gave us the set of water planning programs with which we continue to deal with today. These include the section 201 facilities planning program under Step 1 which then subsequently leads to Step 2 design and Step 3 construction projects, the section 208 water quality management program and the section 303 water quality standard program. These programs resulted in a framework or process which produced literally thousands of national pollutant discharge elimination system permits requiring specific levels of treatment for mun icipally owned wastewater treatment facilities and then, through the process described above, a set of facilities plans recommending treatment solutions to the defined problems.

The Federal Water Pollution Control Act also gave us the first comprehensive involvement in the cost of wastewater treatment services at the local level. Section 204(b)(1) of the statue established the requirement for user charges to be developed for all municipal grantees receiving construction grant funding for wastewater treatment facilities. Briefly, Section 204 required that each applicant for a waste treatment construction grant has adopted, or would adopt, a system charges to assure that each recipient of waste treatment services within the applicant's jurisdiction would pay its proportionate share of the cost of operation and maintenance (including replacement) of any waste treatment services provided by the applicant.

Section 204 of the Law represented a recognition by Congress that the cost for managing waste treatment facilities are in intregal part of the agency's management of the construction grant program and that a system for proportionately distributing the cost of waste treatment services must be established in conjunction with each Step 3 construction grant. It should also be noted that the user charge requirement applied to all facilities within the applicant's jurisdiction, not only the facilities being affected by a given grant project.

To put in perspective the numbers of municipalities and the number of revenue systems that have been approved under the requirements of Section 204, let us briefly look at where the construction grant program has come under Public Law 92-500. To date congressional appropriations for the construction grant programs, through fiscal year 1980, total in excess of $31.5 billion dollars. Correspondingly, actual obligations, in the form of grant awards to cities, towns and villages across the country presently total in excess of $25.7 billion dollars. This $25 billion dollars in obligations represent approximately 18,000 individual grant awards. It is therefore evident that the cost of waste treatment services, the construction grant program and user charge systems have impacted very significant portions of the opoulation within Region V and nationwide. It is currently estimated that on the order of $7 billion dollars is currently collected annually in user charges by local municipal treatment authorities.

Allow me to clarify the definition of user charge systems for the purposes of our discussion. By definition, user charge means: the cost for operation, maintenance and replacement of the treatment facilities. The cost for local debt retirement or the local share of the capital cost are not included in user charge numbers which will be discussed due to the complicating factors of interest rates, methods of bond payback and long term outstanding bond issues.

Subsequent to the passage of Public Law 92-500 it was approximately the end of 1974 until the first user charge system was approved in Region V, that being the first nationwide. Since that time, approximately 700 municipal revenue systems implementing the user charge requirement have been approved in Region V. Those numbers extrapolated to the national level indicates that on the order of 3000 to 3500 user charge systems have to date been reviewed and approved for construction grant projects.

As the program moved through the years of 1975, 1976 and 1977, it became apparent that the process which had been set up was working very well. Hundred of construction grants were awarded, dozens of user charge systems developed under those grant projects were reviewed and approved. It also became apparent, however, that the cost impacts at the local level of these waste treatment construction projects were significant. The impact of these cost considerations was especially large on the very small communities. It should be noted that of the 18,000 existing grant awards that I mentioned earlier, approximately 48% of those grants have been made to communities with populations less than 3500. Another recognition that took place at about the same time was that the process which had been set up, as described earlier, the process of: water quality standards leading to NPDES permits leading to facilities plans, leading to central waste treatment facilities with conventional collection systems had become the order of the day. The potential for these central treatment and collection systems to have significant economic impacts was further compounded by an interest rate which has averaged in the construction industry, and particularly in the waste treatment construction industry, approximately 1% per month. In addition the subject facilities are capital intensive, using large amounts of bricks and mortar and are also energy intensive in terms of necessary killowatts to power aeration blowers, pumps etc.

We have maintained a file of the approximately 700 approved user charge systems in Region V which until recently was in manual form and which has recently been updated and placed on data file in our Regional computer. A data file now named "File of Approved Municipal Revenue System", and nicknamed FOAMRS, is, to the best of our knowledge, the only data file of approved revenue system information of its kind in the country. What that file tells us is that the costs for wastewater treatment vary significantly from community to community. The largest swings are observed between the larger establish municipalities and sanitary districts which have constructed and maintained facilities over the past thirty to forty to fifty years versus the small communities who are attempting to construct new treatment systems using todays inflated construction market

Shown below in table I is a list of municipalities which may be familiar to many of you. These are the larger and older communities around the Region. Listed in the table in addition to the location is the date the revenue system was approved and the annual estimated user cost per connection of per household. It should be remembered that the annual user charge given is for operation, maintenance and replacement and does not include debt retirement which would serve to further increase the total annual charge.

Table I

Location	Date Approved	Estimated Annual Cost
Aurora S.D., Illinois	6/79	$44.00
MSD of Greater Chicago, Il	1/80	$45.00
Springfield S.D., Il	12/79	$65.00
City of Indianapolis, IN	9/77	$47.00
Washtenaw Co./Ann Arbor, MI	7/79	$119.00
Metro Waste Control Comm Serving Minn/St. Paul, MN	9/77	$55.00
Northeast Ohio RSD serving Cleveland, OH	4/76	$59.00

The annual charges shown above should appear typical to most of us here today, and are probably what we expect most people pay for wastewater treatment services. However, these figures can be contrasted with those shown below in table II which are at the other extreme of the cost scale. These are all small communities which have recently undertaken the construction of a new wastewater treatment system or major additions to an existing system. As you can see, the projected annual user cost, per connection, is several times higher than that being experienced in our larger communities. It should be noted that the estimated annual charge of $287.00 is equivalent to almost $24.00 per month, a significant charge in almost anyone's budget.

Table II

Location	Estimated Annual Cost	Population
Village of Elwood, Illinois	$ 215	783
Town of Elnora, Indiana	$ 216	873
Town of Freemont, Indiana	$ 232	1090
Village of Cass City, Michigan	$ 278	2469
Gross Ile Sanitary Drainage District, Michigan	$ 278	--
Village of Butler, Ohio	$ 243	1018
Village of Rock Creek, Ohio	$ 287	800

In response to these spiraling service costs, the Agency first attempted to approach the concern in the form of better publicizing the anticipated cost of wastewater treatment works projects which were still in the planning phase. In this direction, Program Requirements Memorandum (PRM) No. 76-3 entitled, "Presentation of Local Government Cost of Wastewater Treatment Works in Facility Plans" was published in August of 1976. The principal purpose of this document was to ensure that the anticipated costs of the waste treatment alternatives being analyzed in the facilities plans be estimated and displayed clearly for all interested parties to note. The four categories of cost presentation required by the PRM were (a) an estimate of total capital cost, (b) a discussion of the anticipated method of financing, (c) an estimate of the annual operation, maintenance and replacement and a estimate of the monthly charge for debt service retirement.

In addition to the above, a current effort being initiated in the Region is to use the FOAMRS file to close the loop between the cost projections being made in facilities plans and the actual approved costs being identified in the context of approved user charge systems. This will allow for a level of consistency in the cost estimates which has not previously existed.

In addition to highlighting the cost of the proposed treatment facilities, the Agency has also moved to investigate the technological reasons behind these spiraling costs in small communities. One of the most significant advances in the effort to control cost at the small community level was the enactment of the Clean Water Act Amendments of 1977 which included a provision which established the eligibility of on-site treatment systems. Prior to this time, if it was shown that the cost effective solution for a given community was to simply upgrade or improve their existing septic tank based system of treatment, the cost for doing so was entirely a local matter. The Clean Water Act Amendments of 1977 provided the ability to fund, under the construction grant program, the upgrading or necessary replacement of failing septic systems or other on-site treatment methods where it was shown to be cost effective. This initiative of the Clean Water Act has been carried out through the detailing of the necessary procedures to implement on-site system alternatives in PRM 79-8, titled: "Small Wastewater Systems" published in May of 1979 and subsequently in a step-by-step guidance document developed here in Region V during the Spring of this year.

The intent of this effort has been to give on-site treatment systems every chance of working in order to provide reliable treatment services at a reasonable cost to the local home owner.

In addition to the on-site systems initiative for the smaller communities, the program has also strongly encouraged systems in the mid and large size municipalities which focus on energy conservation and other forms of innovative and alternative technology. A good example of this is a current project in Muncie, Indiana where some 25 municipal vehicles will be powered by the methane gas produced in the anarobic digesters at the wastewater treatment facilities.

This, for the most part, summarizes where the Agency and the construction grant program have come in terms of the issue of costs for wastewater treatment services. What I would like to do now is to briefly outline what our current concerns are and where we see ourselves moving during the years to come.

Currently underway at the National level and at the direction of Chris Beck, the Assistant Administrator for Water and Waste Management is what is termed the 1990s study. The purpose of this effort is to identify where the construction grant program should be in 1990. The format for the effort focuses on five major tasks within which approximately 60 issue papers will be developed, each outlining an array of options being considered.

One of the major papers being prepared under the 1990 effort is one addressing the issue of the financial management of publicly owned treatment works funded under the construction grant program. The primary focus of that paper is the long term economic self sufficiency of publicly owned treatment works including the subject of local responsibilities relative to reconstruction or recapitalization. Matters being considered within the analysis include: (a) what should be required in terms of a thorough financial analysis during Step 1 facilities planning, (b) user charge systems which include reconstruction/recapitalization recognition, (c) fixed asset and preventive maintenance management systems developed as a intergral part of construction projects and (d) follow-up by State or Federal program representatives to monitor the financial management of constructed facilities by grantees. It is expected that the 1990s study will be completed by the end of this calendar year.

In conclusion, the issues related to the costs of wastewater treatment have evolved over the last seven to eight years in the context of the construction grant program and will continue to undergo further analysis and refinement as we move into the 1980s and approach 1990.

WATER SHED

A MANAGEMENT TECHNIQUE FOR CHOOSING AMONG POINT AND NONPOINT CONTROL STRATEGIES

PART I - THEORY AND PROCESS FRAMEWORK

by

William C. Sonzogni
Timothy J. Monteith
Thomas M. Heidtke
Rose Ann C. Sullivan

Great Lakes Basin Commission Staff

To be presented at

U.S. EPA, Region V, Seminar on
WATER QUALITY MANAGEMENT TRADE-OFFS
September 16 and 17, 1980

A MANAGEMENT TECHNIQUE FOR CHOOSING AMONG POINT AND NONPOINT CONTROL STRATEGIES

PART 1 - THEORY AND PROCESS FRAMEWORK

by

William C. Sonzogni, Timothy J. Monteith,
Thomas M. Heidtke, and Rose Ann C. Sullivan*

Abstract: To assist water quality managers and planners in formulating cost-effective pollution control strategies, a methodology was developed for evaluating alternative point and nonpoint source control within a drainage area. The methodology -- referred to as WATERSHED -- allows the user(s) to estimate loadings from each major pollutant source and to examine load reductions and costs associated with control options. Point and nonpoint source control strategies can then be ranked on the basis of cost per unit reduction in pollutant loading to the receiving water. From this ranking, an optimum mix of programs can be identified which will achieve a required load reduction at least cost. Strategies can be staged, that is, they may consist of several levels of control.

In evaluating loadings and control programs for a given drainage area, WATERSHED considers the hydrologic, physiographic and demographic characteristics of the basin, pollutant losses or entrapment during transport from source to river mouth, as well as the bioavailability of the pollutant(s) under study. The approach is flexible and able to accommodate a variety of techniques for estimating loadings from municipal and industrial point sources and land runoff. Although WATERSHED is primarily a data integration and accounting system (rather than a technique to generate point and nonpoint loads), some methods for estimating loads are specifically addressed. Calculating cropland loads based on potential gross erosion determined from the Universal Soil Loss Equation (USLE) was found to be particularly useful, since the effect of control programs can be evaluated based on changes in the factors governing the USLE. A case study of how WATERSHED can be applied to the Sandusky River basin in northcentral Ohio is presented in a companion paper.

---

* Great Lakes Basin Commission Staff. Water Resources Scientist, Water Resources Engineers, Regional Planner/Policy Analyst, respectively. Great Lakes Basin Commission, Ann Arbor, Michigan.

INTRODUCTION

Water quality managers and planners are faced with difficult decisions on how to best reduce point and nonpoint pollutant inputs to water bodies. Given the economic realities of today (reduced government spending, inflation and high energy costs), these decisions must be cost-effective. Decision-makers must, therefore, be careful to select the combinations of point and nonpoint water quality control measures which will most efficiently solve their pollution problems.

Recognizing the difficulty in choosing among point and nonpoint control strategies within any given drainage basin, the U.S. Environmental Protection Agency (Region V) asked the Great Lakes Basin Commission staff to assist them in devising a straightforward technique for choosing among river basin management options. This paper describes the technique developed. A companion paper will show how the technique can be applied using a simple worksheet system (Monteith et al., 1980). To complete the effort a handbook will be prepared (summer, 1981) to facilitate application of the technique.

The management technique developed, called "WATERSHED", is basically an accounting system for assessing and comparing alternative management strategies to control point and nonpoint (excluding atmospheric) source pollution inputs to a receiving water. It provides a means for evaluating the fraction of the total pollutant input attributable to any particular source, as well as how cost-effectively this input can be controlled relative to the input from other sources. WATERSHED utilizes information on the geophysical and demographic characteristics of a drainage area, along with the costs of remedial measures, to generate the least-cost program (or sequence of programs) for attaining a required level of pollutant load reduction. WATERSHED is unique in that it integrates a wide range of technical information on both point and nonpoint pollution control. It attempts to quantify and practically apply information generated from years of research and demonstration.

WATERSHED has evolved from several studies, including the Pollution from Land Use Activities Reference Group (PLUARG) study, the Lake Erie Wastewater Management Study (LEWMS); the Black Creek (Ohio), Washington County (Wisconsin), and Red Clay Erosion (Wisconsin) demonstration projects conducted under Section 108 of Public Law 92-500; a host of studies conducted under Section 208 of Public Law 92-500; and the innovative Wisconsin Fund program. The interrelationships among these studies, as well as details of the studies themselves, are summarized in Sullivan et al. (1980a and b).

Although all of the above studies have contributed to the development of WATERSHED, its foundation lies in the "overview modeling" process developed as part of the PLUARG study (Johnson et al., 1978; Heidtke, 1979; Heidtke et al., 1979). PLUARG was a multi-million dollar cooperative investigation of nonpoint source pollution in the Great Lakes basin. In PLUARG, overview modeling was used to identify the most cost-effective mix of point and nonpoint controls in each of the Great Lakes basin watersheds. The process provided detailed estimates of pollutant inputs from each major source in each of the drainage areas or streams discharging to the lakes. Because of the large number of computations frequently involved in arriving at these estimates, a computer program was used to simplify the accounting procedure.

The overview modeling process considers factors such as varying land use (such as farmland, forest and wetlands) and land form (soil texture and slope), as well as different types of urban areas. The modeling process is dynamic, enabling one to take into account changing conditions such as population growth, urbanization of rural areas, or the natural removal of pollutants from the water as it moves downstream to the lake.

The value of the process is fully realized when pollution control information is introduced into the computations. Alternatives for reducing phosphorus inputs from each source can then be tested. Then those measures which produce the greatest pollutant reduction at least cost can be easily identified.

Although the overview model provides the basis for WATERSHED, WATERSHED is much more flexible and easier to use. PLUARG's overview model is basically a research tool, while WATERSHED is designed to be more user-oriented.

While WATERSHED is applicable to many nonpoint pollutants, it has been developed with phosphorus and suspended sediment primarily in mind. Some slight modifications to the approach may be necessary to accommodate the unique characteristics of other pollutants. For an example of how the basic approach can be applied to other parameters, see Heidtke et al., 1980).

SYNOPSIS OF THE "WATERSHED" PROCESS

The initial step in WATERSHED is division of a river or drainage basin into sub-basin units. Point and nonpoint sources in these sub-basins are then identified and their respective pollutant inputs are estimated. An accounting system is then used to route the inputs downstream to the receiving water. This accounting can be performed manually or with the aid of a computer. Transmission losses, which may occur due to a reservoir or other obstruction, are estimated through the application of "transmission coefficients" in various stretches of the tributary. The percent of the pollutant that is likely to reach the receiving water in a biologically available form can also be factored in. Remedial measures can be compared in terms of cost per unit reduction in pollutant input at the receiving water to account for differences between upstream and downstream sources. This basic "accounting system" is readily adaptable to large or small watersheds and can be as general as the user desires.

Techniques for estimating pollutant loads (when these loads are not already monitored) are based on the most accurate and up-to-date information available. For agricultural land, the Universal Soil Loss Equation (USLE) is used in evaluating the effect of various management techniques, such as conservation tillage, on loadings from agricultural land. This allows load reductions to be related to a series of established factors that affect soil erosion losses from land. Widespread use of the USLE in the field has established its validity and utility for this purpose.

The WATERSHED approach can next be used to choose the best mix of point and nonpoint management techniques to achieve a certain load allocation for a receiving water body. Through a cost-effectiveness ranking scheme, WATERSHED shows the order in which remedial measures should be implemented to achieve the greatest water quality improvements at the least cost.

Thus, WATERSHED provides planners and managers with a logical guide to select among point and nonpoint water quality control programs. It will be most valuable if used with the assistance of individuals or agencies familiar with the specific characteristics of the hydrologic basin under study. WATERSHED's straightforward accounting should be applicable to most river basins, but its application should be customized through the use of local information and expertise whenever possible.

CONCEPTUAL LAYOUT OF THE STUDY AREA

To proceed with the WATERSHED process, a drainage basin is first divided into a set of sub-basins. Urban areas and point source discharges within each sub-basin are identified, as well as locations along the main channel where the point source and diffuse pollutant loadings are assumed to enter. Physical characteristics of the river which may cause pollutant transmission losses are then identified. The resulting framework conceptualizes a drainage basin as a series of discrete pollutant loadings proceeding in sequence from the headwaters downstream to the river mouth (see Figure 1). A more detailed discussion of this layout process follows.

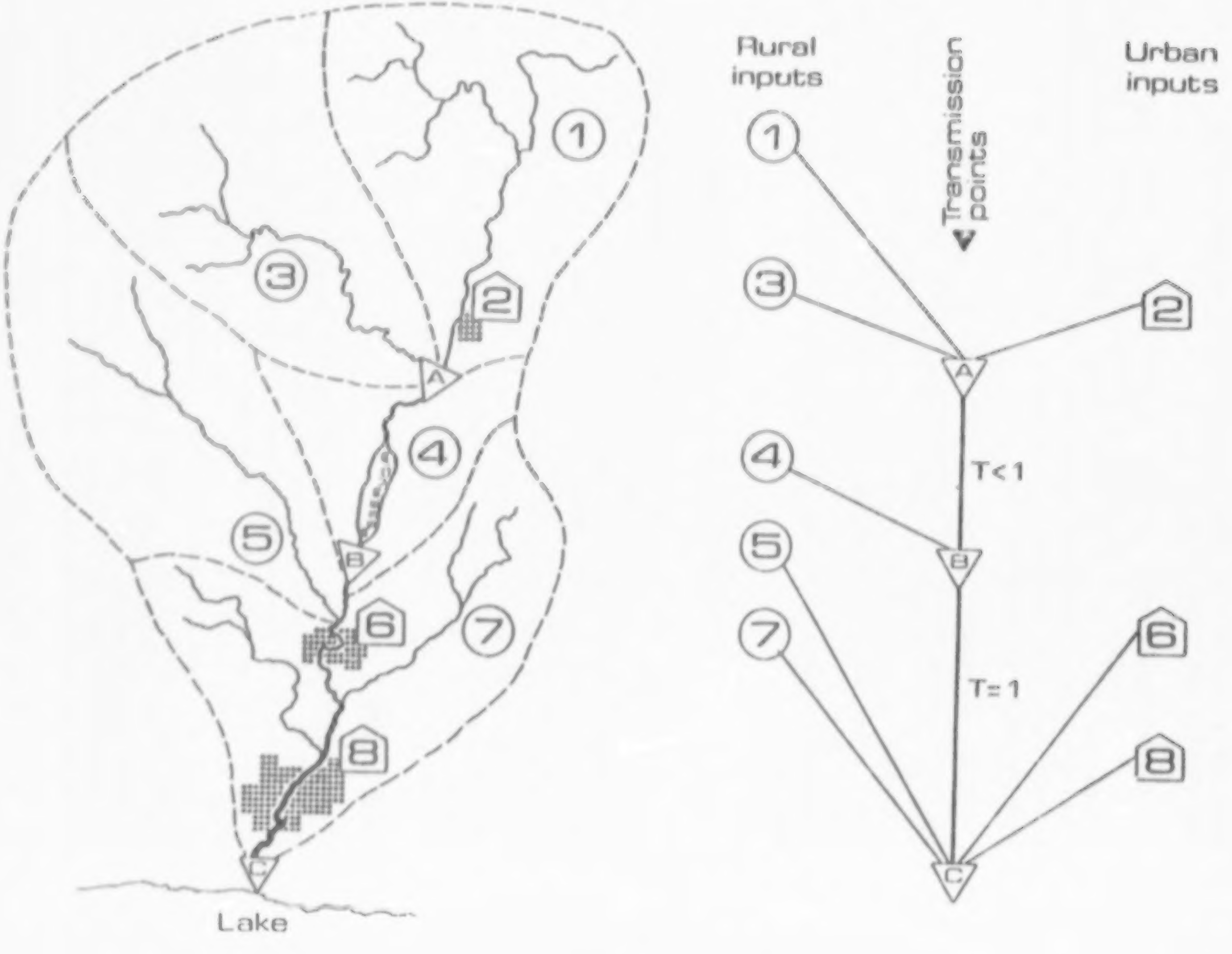
Constructing Sub-Basins

The initial step in establishing sub-basins for a particular study area is to divide the region into smaller hydrologic units. These may be defined from Conservation Needs Inventory hydrological maps or from analysis of any available physiographic maps of the drainage area. Once the boundaries of individual hydrologic units have been delineated, each is then further divided into areas with relatively homogeneous surface soil texture and topography. Information on soil textures and distributions can generally be obtained from county soil surveys published by the U.S. Soil Conservation Service (SCS) and through the assistance of local SCS personnel. The resulting divisions are referred to as "sub-basins" of the drainage area under study.

If desired, the sub-basins may be further broken down on the basis of land use intensity (i.e., cropland, pasture, grassland, forest and

FIGURE 1

RIVER BASIN AND ITS SCHEMATIC REPRESENTATION


1
2
3
4
5
6
7
8
A
B
C
Lake
Rural inputs
Transmission points
Urban inputs
T<1
T=1

wetlands). However, this level of refinement is unnecessary for application of the WATERSHED process.

Components of the Sub-Basins

After establishing sub-basin boundaries, it is necessary to identify and define critical characteristics of the urban and rural land contained within each sub-basin. This information is necessary to accurately assess pollutant loadings and the effect of remedial measures.

Point Source Discharges: All significant point sources discharging to surface waters of the sub-basin must be identified. For each point source, the following data are required:

1) Pollutant load, or
2) Average wastewater flow and average effluent concentration for the pollutant(s) under study.

For municipal wastewater treatment plants, it is also important to obtain an estimate of the population served by the facility as well as data on performance history, type of treatment system in effect (primary, secondary, or tertiary) and plans for future expansion. All of these factors are useful in evaluating point source pollutant loadings and control programs within each sub-basin.

Urban Land: Urban areas within each WATERSHED sub-basin are identified and separated from the rural land. For each urban area, the following statistics should be determined:

1) total area
2) area served by combined sewers
3) area served by separate sewers
4) unsewered area.

For small cities it is generally sufficient to only determine the boundaries of the urban land. However, to ensure an accurate analysis of pollutant loadings and control measures in larger urban areas (e.g., populations exceeding 10,000), it is desirable to obtain estimates of combined, separate and unsewered areas. Information on urban areas may be obtained from the Bureau of the Census, "208" water quality management plans, or other state, county and local sources. The U.S. Environmental Protection Agency (1977) has compiled information on areas served by different types of sewer systems in large cities.

To more accurately describe an urban area, additional information should be obtained on the degree of industrialization and the amount of urban development. Industrial activity can significantly affect the concentration of pollutants in urban runoff, whereas developing land generally contributes the largest suspended solids loading per unit area.

Rural Land: After the areas of urban land have been identified for a given sub-basin, the remaining rural area is broken down into different land use categories (e.g., row crop, mixed farming, pasture, grassland, forest and wetlands). Because agricultural areas are generally responsible for the greatest diffuse pollutant load per unit area of rural land and represent the focus of nonpoint source control programs on rural land, it is critical that these areas be accurately identified. Here, again, information on rural land uses may be obtained from "208" water quality management plans, the U.S. Department of Agriculture's Conservation Needs Inventory and its system of Land Capability Units, or other appropriate sources. Within the Great Lakes basin, remote sensing techniques have been used to classify hydrologic areas according to different land covers including forest, wetland, grassland and agricultural land. This information has been compiled by Monteith and Jarecki (1978).

Points of Entry and Transmission Coefficients

Once the sub-basin boundaries have been defined and the major sources of pollutant loadings have been identified and characterized (i.e., urban and rural runoff and municipal and industrial point source discharges), locations where these loadings enter the main channel must be determined (see Figure 1). The WATERSHED methodology assumes that all point and diffuse pollutant sources within a given sub-basin enter the main channel at discrete positions referred to as "points of entry". Loadings from several sub-basins may discharge to the same point of entry. There is no fixed rule for identifying points of entry; this particular step requires sound judgment in combination with knowledge of the pollutant(s) under study and the physical characteristics of the main river or stream. In general, points of entry correspond to intersections of feeder streams with the main channel, or to positions upstream and downstream of river features which could retain material moving downstream (e.g., a reservoir or a low-gradient flood plain).

Each river stretch -- a section of river between any two points of entry -- has a transmission coefficient associated with it. For any river stretch, this coefficient represents the fraction of pollutant which is transmitted from the upstream point of entry to the downstream point of entry in the river channel. This feature of WATERSHED allows the user to account for pollutant losses within the river.

CHARACTERIZATION OF POLLUTANT LOADS

Once the hydrologic basin has been characterized geophysically, the loads of pollution sources must be determined. In many cases the load emanating from a particular pollution source is not monitored. Below are different methods of estimating pollutant loads from different sources. The methods take into account the key factors that have been identified as affecting loads from various sources and represent state-of-the-art knowledge in the nonpoint source pollution field. The methods were specifically developed for estimating phosphorus and suspended sediment loads, but can be customized for use with other pollutants.

Measured Loads

Whenever possible measured loads, based on properly designed sampling programs, should be used to determine loads from point or nonpoint sources. In most cases, however, such information will not be available, although sampling programs have been established near the mouths of many large river basins (river mouth loads are particularly helpful for calibrating results. This will be discussed in a subsequent section).

Where information from sampling programs is available, loads should be determined (from flow and concentration measurements) using a calculation technique that accounts for the importance of high flow events. An example of one such technique is the ratio estimator technique (IJC, 1976).

River mouth loads used in WATERSHED should always be adjusted to historical average flows. A technique for adjusting river mouth loads to base year conditions is given in Sonzogni *et al.* (1979).

Point Source Loads

Municipal Point Sources: In most cases, data on municipal point source effluent loadings will be available for parameters such as phosphorus and suspended solids. The U.S. Environmental Protection Agency, state governments and many regional planning agencies maintain inventories of point sources. While these inventories do not always contain annual loads for point sources, they usually provide flow and chemical concentration data which can be used to calculate loads.

If sufficient data are not available to permit calculation of the annual load from a point source, an estimate can often be made if certain characteristics of the point source are known. Such estimates are most readily made for municipal sewage treatment plant point sources. Municipal point source loads can be estimated from typical per capita flows and typical concentrations for different degrees of wastewater treatment reported in Sonzogni *et al.* (1978) and Heidtke *et al.* (1979).

Industrial Point Sources: Industrial point sources, which often have complex wastewaters and highly specialized treatment technologies, are difficult to estimate without empirical data. However, industrial inputs are, in many cases, a small part of the total load of pollutants. For phosphorus inputs in particular, it has been shown in the Great Lakes basin that industrial phosphorus inputs are small relative to loads from other sources and can generally be ignored (PLUARG, 1978; Heidtke *et al.*, 1979; Sonzogni *et al.*, 1980). Further, it has been found that industrial toxic metal loads to Lake Michigan currently comprise a very small percentage of the total input of metals from all sources (Sullivan *et al.*, 1980). Consequently, the lack of industrial loading data may not be a severe constraint for many basins.

Urban Nonpoint Loads

One approach for estimating loads from urban nonpoint sources if measurements cannot be made, is to use urban storm runoff models such as "STORM" (U.S. Army Corps of Engineers, 1975) or "LANDRUN" (Novotny *et al.*, 1979). If a lack of data precludes the use of such models or if a simpler approach is desired, annual unit area loads (UALs) (amount of pollutant delivered per unit area of basin) may be used to estimate loads. Typical UALs for different classes of urban land are presented in Table 1. Note that the UALs are dependent on (1) the type of sewerage system in place, and (2) the degree of industrialization.

Table 1 presents UALs of total phosphorus attributable to urban runoff. These values were used in the Pollution from Land Use Activities Reference Group (PLUARG) study (PLUARG, 1978; Johnson *et al.*, 1980) and were derived from extensive data collected during several pilot watershed studies within the Great Lakes basin.

As shown in Table 1, the UALs from combined sewer areas are considerably higher than those from separate and unsewered areas. This is because total phosphorus loadings from combined sewer overflows are incorporated into the UAL estimates for these areas. To confirm these high values, information on combined sewer areas and overflow loadings within southeast Michigan was examined. According to SEMCOG (1978), combined sewer overflows discharge approximately 450-600 metric tons of total phosphorus annually to lakes and streams in southeast Michigan. The approximate urban area served by combined sewers in this region is 650-800 km^2. This converts to a UAL ranging from 600-900 kg/km^2/yr, and is consistent with the 700-800 kg/km^2/yr difference between UALs presented in Table 1 for combined and separate sewered areas.

The effect of industrialization on UALs from urban land is also noted in Table 1. Because industrial activity is generally accompanied by accumulations on the land surface of particulate matter from stack emissions and heavy transportation, UALs of several pollutants tend to be higher in these areas (Marsalek, 1978).

Developing urban land (construction sites) represents a special case in that UALs of sediment and sediment-associated pollutants are generally several times greater than those from other urban areas. Johnson *et al.* (1978) reported a value of 225 mt/km^2 of suspended solids per year for developing land which is 3-5 times greater than the UAL from separate, combined or unsewered areas. Similarly, compartively high contributions from developing urban land have been reported by Chesters *et al.* (1980) in their extensive study of the Menomonee basin in metropolitan Milwaukee. Developing urban land generally comprises a small portion of the total urban area, but can be important if extensive construction is occuring.

Table 1 gives UALs for urban lands that are typical of the Great Lakes area. For areas of the country where the annual rainfall is significantly different from the Great Lakes region, UALs should be adjusted accordingly.

TABLE 1

TOTAL PHOSPHORUS UNIT AREA LOADS FOR URBAN LAND[a]

URBAN LAND CLASSIFICATION	TOTAL PHOSPHORUS UAL ($kg/km^2/yr$)		
	DEGREE OF INDUSTRIALIZATION		
	Low	Medium	High
Combined Sewered Areas	900	1,000	1,100
Separate Sewered Areas	125	250	300
Unsewered Areas	125	--	--
Small Urban Areas (Sewer system not differentiated)	250	250	250
Urbanizing Land	2,500	2,500	2,500

[a] Adapted from PLUARG (1978).

Rural Runoff Loads

Ideally, runoff loads from each sub-basin should be based on actual measurements. However, such data are usually unavailable. Further, it is usually not possible to distinguish the individual contributions of different sub-basin land uses (e.g., cropland, woodland, grassland, urban land) from the load measured at the mouth of the sub-basin.

A variety of techniques exist for estimating rural runoff loads when direct measurements of loads are not available. Various deterministic mathematical models exist that allow generation of various runoff parameters (Heidtke, 1979; Heidtke and Sonzogni, 1979). These models -- for example "ANSWERS" (Beasley et al., 1977) and "CREAMS" (Knisel, 1980) -- are applicable only to very small areas. Typically the models require detailed data that do not exist for many basins.

Many of the models that have been developed to date are based on the Universal Soil Loss Equation (USLE). The USLE groups factors influencing erosion under six major terms that can be expressed numerically. The numerical values for these terms, derived from several decades of information-gathering and research, have been established for specific sites throughout the United States. Several references exist which explain the USLE (e.g., Wischmeier and Smith, 1978).

Because the USLE is established and widely used, particularly in the evaluation of rural runoff control strategies, it is desirable to utilize it in estimating loads. One of the major problems with using the USLE is that it provides an estimation of potential gross erosion of sediment rather than sediment yield (or load). Sediment yield is the amount of sediment that actually reaches the main channel. Potential gross erosion must be multiplied by a factor, termed the delivery ratio (DR), to estimate sediment yield.

Unfortunately, no agreed-upon method has been derived to estimate sediment delivery ratios. Stewart et al (1975) indicate that the delivery ratio has been observed to be roughly inversely proportional to the 0.2 power of the drainage area (in acres). However, such a relationship, because of its exponential nature, makes little distinction in delivery ratios for basins over about 40 to 50 acres in size. Other factors, such as surface soil texture, drainage density and slope may have a more significant effect on the delivery ratio than area drained.

The surface soil texture may be particularly important to delivery. In the Great Lakes basin, it has been found that areas with predominately clay surface soils often have relatively low potential gross erosion rates but high yields of sediment and associated pollutants (PLUARG, 1978). Although McElroy et al. (1976) have attempted to relate soil texture to delivery ratio, the relationship is not readily usable. Clearly, development of a widely applicable equation for sediment delivery ratios to allow direct calculation of sediment yield from potentional gross erosion remains a major research question.

Potential gross erosion, as calculated from the USLE, also does not provide information on chemical pollution (e.g., phosphorus) from runoff. The amount of pollutant delivered is often calculated by multiplying sediment yield by the proportion of chemical contained in the sediment and then by an enrichment ratio. The enrichment ratio accounts for the fact that the pollutant yield is often a different percentage of the sediment yield than the average percent composition of the pollutant in the sediment. Taking phosphorus as an example, an enrichment ratio can be used to account for preferential delivery of clay-sized particles which, because of their physical properties, tend to have more phosphorus associated with them than larger particles.

In WATERSHED, the conversion of potential gross erosion to the yield of a chemical pollutant is accomplished by multiplying gross erosion by a single factor termed the "pollutant delivery ratio". This operationally defined coefficient groups chemical enrichment, sediment delivery and other factors into an overall term. Its use is further explained in the companion case study of the Sandusky River Basin (Monteith et. al., 1980).

When it is not necessary or desirable to relate pollutant yield to USLE factors, the yield of a pollutant can be estimated directly from UALs. This is possible because a UAL is, in fact, an estimate of pollutant yield, since delivery and enrichment are intrinsic to UALs.

Several procedures for estimating loads or yields of pollutants from rural land are presented in the following section. These procedures are based on the concepts discussed above. Cropland and non-cropland are treated separately.

Rural Non-Cropland: For non-cropland rural areas such as forests, grasslands and marshland, pollutant yields are best estimated from UALs such as those shown in Table 2. The area of a particular land use (or use intensity) is simply multiplied by the appropriate UALs to estimate the load. The non-cropland UALs in Table 2 are based on Johnson et. al. (1980) and PLUARG (1978), but should be representative of most areas of the United States since studies of non-cropland areas show consistently low land drainage loads. For example, in PLUARG it was concluded that forested and idle land contribute one to two orders of magnitude fewer pollutants per unit area than cropland or urban land (Sonzogni et. al., 1980).

Cropland

As mentioned previously, determining loads from cropland is especially important, since management of cropland will offer the greatest potential for pollutant reductions from land runoff in many areas. Pollutant losses from cropland, especially land in row crops, also tend to vary from site to site more than losses from other types of land. This variability has been illustrated statistically by Reckhow et al. (1980).

One of the principal conclusions from PLUARG was that land use is not the only variable influencing pollution from land runoff. Other

TABLE 2

TOTAL PHOSPHORUS UNIT AREA LOADS FOR RURAL LAND[a]

LAND USE INTENSITY	TOTAL PHOSPHORUS UAL (kg/km^2/yr)					
	TYPE OF SOIL					
	Sand	Coarse Loam	Medium Loam	Fine Loam	Clay	Organic
Rural Cropland						
Cultivated Fields - row crop (low animal density)	25	65	85	105	125[b]	--
Cultivated Fields - mixed farming (medium animal density)	10	20	30	55	85	--
Rural Non-Cropland						
Pasture/Range - dairy	5	5	10	40	60	--
Grassland	5	5	10	15	25	--
Forest	5	--	--	--	10[c]	--
Wetlands	--	--	--	--	--	0

[a] Adapted from PLUARG (1978).

[b] Unit area loads may be higher when soil has an unusually high clay content.

[c] Unit area loads may be higher in certain unique forested areas with clay soils.

factors which often explain the large range in contributions from single land uses are: land form (characteristics of the land itself, such as surface soil texture, slope and the chemical characteristics of the soil), land use intensity, materials usage and meteorology (Sonzogni _et al._, 1980). The impact that some of these factors have on phosphorus losses from cropland can be seen in Table 2 where UALs from various land uses and soils are presented.

As can be seen from Table 2, surface soil texture was found to be a particularly important determinant. Some factors, such as materials usage (e.g., amount and technique of fertilizer application), are not easily quantified for the general case, so the values in Table 2 must be tempered with the users' judgment and knowledge of the study area.

It is also possible to adjust the UALs in Table 2 to account for differences in the slope of the land. The effect of slope on UALs is shown in a more detailed UAL table in Johnson _et al._ (1980).

While Table 2 could be used to estimate loads directly, it is often desirable to relate cropland loads to potential gross erosion calculated from the USLE (for reasons discussed previously). In order to establish this relationship, the pollutant delivery ratio must be estimated for the cropland under consideration. Since an acceptable technique for directly determining delivery ratios for cropland has not been established (see previous section), they must be estimated using erosion and loading data.

Procedures for estimating delivery ratios under two different river basin data packages follow:

1. _Pollutant Yield of Sub-Basin Known (measured)_

   If the load (yield) of a pollutant from a sub-basin is known from a monitoring program, the pollutant delivery ratio for a cropland area is calculated by first subtracting from the monitored load the total non-cropland contributions (point sources, urban runoff and rural non-cropland runoff). The resulting cropland pollutant load is then divided by the potential gross erosion calculated for cropland area to get a pollutant delivery ratio. The following equation describes this process:

$$L_{\text{cropland}} = L_{\text{total sub-basin}} - L_{\text{total non-cropland}} \tag{1}$$

$$PDR_{\text{cropland}} = \frac{L\ \text{cropland}}{E\ \text{cropland}} \tag{2}$$

where:

L_{cropland} = Pollutant load (yield) from cropland (mt/yr)

$L_{\text{total sub-basin}}$ = Total pollutant load from sub-basin (mt/yr)

$L_{\text{total non-cropland}}$ = Pollutant load not attributable to cropland (mt/yr)

PDR_{cropland} = Pollutant Delivery Ratio for cropland (dimensionless)

E_{cropland} = Potential gross erosion for total cropland area (mt/yr)

$L_{\text{total non-cropland}}$, which includes contributions from such sources as point sources, urban runoff and rural non-cropland, may be estimated (when not known) from techniques described earlier.

2. Pollutant Yield of Sub-Basin Not Known

In the majority of cases, loads from sub-basins will not have been measured. In these situtions several techniques can be used for estimating delivery ratios.

Perhaps the simplest means of getting a pollutant delivery ratio is to use the value from a monitored sub-basin with similar characteristics. If the pollutant delivery ratio can be calculated for one sub-basin using the procedure described above, this delivery ratio could be used for other sub-basins which are expected to behave similarly.

Another straightforward technique is to estimate cropland loads based on the sub-basin cropland area and an appropriate UAL, (for example, as given in Table 2). The pollutant delivery ratio is then calculated from equation 2.

Finally, it is possible to calculate a cropland pollutant delivery ratio when the load for the entire basin (as opposed to sub-basin) is known. Such data frequently exist, since monitoring programs near river mouths are common. In this case, the total non-cropland load for the entire basin is subtracted from the total known pollutant load at the mouth to give the cropland load for the basin. The cropland pollutant delivery ratio is then calculated by dividing the cropland load by the cropland total potential gross erosion (mt/yr). These calculations are analagous to those illustrated in equations 1 and 2 except that they are carried out for the entire basin rather than a single sub-basin.

The resultant pollutant delivery ratio is thus an average for the entire basin. This pollutant delivery ratio can be used for each of the sub-basins, provided the characteristics of the sub-basins (e.g., soil texture) are similar, and provided upstream pollutant inputs do not undergo significant transmission losses before reaching the river mouth.

Other Sources of Pollution

Septic Tanks: Private waste disposal systems or septic tanks are often implicated as a source of pollution in rural or unsewered urban areas. However, most field investigations have shown that only a small percentage of the total pollutant input to a river basin comes from septic tank discharges (Jones and Lee, 1979; Krause and Pilling, 1979). For phosphorus in particular, septic tank discharges are generally a very small part of the phosphorus load from all sources, even in basins with sandy soils.

In order to estimate septic tank inputs of pollutants for a sub-basin, an annual per capita contribution should be multiplied by the number of residents in the sub-basin using malfunctioning septic tanks. If the private waste disposal units are used only seasonally, an appropriate correction should be made.

A per capita contribution of about 1.5 kg/ha-yr appears to be typical of most septic tank operations (Reckhow et al., 1980). Where a detergent ban is in effect, the per capita input may be lowered by 30 to 40 percent. Septic tank inputs are treated as a point source in the WATERSHED process.

Streambank Erosion: Streambank erosion was extensively studied during PLUARG, but was found to account for only a small part of the total sediment load to the Great Lakes. The phosphorus contribution was found to be even less significant relative to other sources since streambank materials tend to be lower in phosphorus than topsoil eroded from fields. Even the streambank erosion sediment contribution to the Cuyahoga River, once thought to be very significant relative to other sources, has been found to be small according to preliminary results of a study of streambank erosion along the river (Urban, 1980). In most situations, then, streambank erosion should be ignored as a separate pollutant source.

Feedlots: Feedlots can be a significant source of pollution in rural areas and should be assessed in a basin analysis. Various techniques exist to estimate feedlot contributions, which depend on factors such as the number and types of animals using the feedlot and its physical layout. Studies done on contributions of pollutants from feedlots show that the amounts vary widely (Reckhow et al., 1980). When it is suspected that feedlots in a sub-basin may be important but their contributions are not known, their relative importance can still be assessed through WATERSHED by considering a range of assumed values. If, for example, the maximum likely value (such as might be determined from Reckhow et al., 1980) is found to result in a low or insignificant pollutant load compared to other sources, the contribution of feedlots may be neglected. Likewise, if the minimum UAL produces significant contributions, then feedlots need to be given more attention in a pollutant control program for the basin. Feedlots should be considered as point sources in WATERSHED.

Miscellaneous Sources: Additional sources of pollution to a river basin include landfills and other waste disposal areas, sludge disposal sites, mining operations, chemical storage areas, lagoons, and land areas used for wastewater application (e.g., spray irrigation sites), recreational land, and wildlife (e.g., large geese concentrations). In most cases, loads from these sources are small compared to loads from land runoff (PLUARG, 1978). In cases where one or more of these sources are suspected of being significant, an estimate can be made of their pollution contribution and their relative importance assessed in the WATERSHED process, since WATERSHED is flexible enough to consider any sources desired. When an estimate of a load cannot easily be made, a likely range of loads (maximum and minimum loads) can be estimated and the importance assessed under either extreme. For example, if the maximum load expected is low compared to that from other sources, the source in question can be ignored.

BIOLOGICAL AVAILABILITY

A portion of the load of certain pollutants may be in a chemical form that does not stimulate biological growth. In the case of phosphorus, a substantial portion of the total phosphorus load may be in a form unavailable for biological uptake. Availability is especially important when comparing the cost-effectiveness of control alternatives. Otherwise, funds could be wasted on controlling a pollutant that does not substantially affect water quality.

While information on availability is presently incomplete, enough information does exist, particularly for phosphorus, to make some generalizations that can be applied in WATERSHED. Sonzogni et al. (1980) recently reviewed the existing information on phosphorus availability. Table 3 is based on their review.

Table 3 shows that the bioavailability of phosphorus in runoff water is consistently low. In contrast, phosphorus in municipal point source discharges is largely available, at least compared to other sources. Based on limited data, the type of sewage treatment or phosphorus removal practices does not appear to affect the bioavailable fraction of phosphorus in the effluent.

Because the bioavailability of phosphorus between point and nonpoint sources seems to differ widely, it is important that it be considered in certain cost-effectiveness factors. In WATERSHED, the bioavailable pollutant load from a particular source is estimated by multiplying the total load from that source by the bioavailable fraction. Since the bioavailable fraction will almost never be established for an individual source, the value must be estimated. In most situations, it is advisable to assume a range of bioavailable fractions to ascertain the sensitivity of the results to these different assumptions.

TABLE 3

GENERALIZATIONS ON THE AVAILABILITY OF PHOSPHORUS DERIVED FROM DIFFERENT SOURCES

(Based Mostly on Great Lake Studies)

Form and Source	Approx. % Available Phosphorus
Particulate P in River Water	40 or less
Total P in River Water	50-60 or less
Particulate P in Urban Runoff	50 or less
Total P in Rural Runoff	50 or less
Total P in Municipal Point Source Discharges	70 or more

DOWNSTREAM TRANSMISSION

Once the pollutant inputs have been identified and quantified, the loadings from all sub-basins must be routed downstream from points of entry to the receiving water (river mouth). As discussed previously, each reach of the river (section of river between two points of entry) has a transmission coefficient (t) associated with it. This coefficient represents the fraction of pollutant load which is transmitted between adjacent points of entry. For any given entry point, the "effective transmission" (T) is defined as the fraction of the total pollutant load at that point which is delivered to the downstream receiving water. In other words, "T" is the product of all downstream transmission coefficients "t".

The concept of transmission is further illustrated in Figure 2. If the transmission coefficients t_1 and t_2 assume the values 0.5 (50 percent of the pollutant load entering point A is lost by the time it reaches point B) and 0.8 (20 percent loss), respectively, the effective transmission of the pollutant load entering at point A (T_A) would be 0.4 ($T_A = 0.5 \times 0.8$). Thus, if the pollutant load introduced at point A were 100 mt/yr, only 40 percent, or 40 mt/yr, would reach the downstream receiving water. At point of entry B the effective transmission T_B is the same as the transmission coefficient (t_2) since there are no further downstream transmission losses. Thus, the total load to the receiving water in Figure 2 is 104 mt/yr.

Importantly, if a control program reduced the pollutant load at point A by 50 mt/yr (50 percent reduction), the resultant load delivered to the receiving water would not be reduced by 50 mt/yr. As the example in Figure 2 illustrates, the annual load at the receiving water would be reduced by only 20 mt/yr. The new load, as shown in Figure 2, would be 84 mt/yr. Accordingly, if the effectiveness of a control is judged by the amount of pollutant reduction achieved at the receiving water, transmission is a salient consideration.

For some pollutants, including phosphorus, transmission losses are often small, especially over the long term (PLUARG, 1978; Verhoff *et al.*, 1978). This is particularly true when a large fraction of the pollutants under consideration are associated with clay-size particles which are easily suspended and transported. In most cases, only those tributaries with large impoundments or large flood plains will require adjustments for transmission.

Summary of Load Calculation Technique

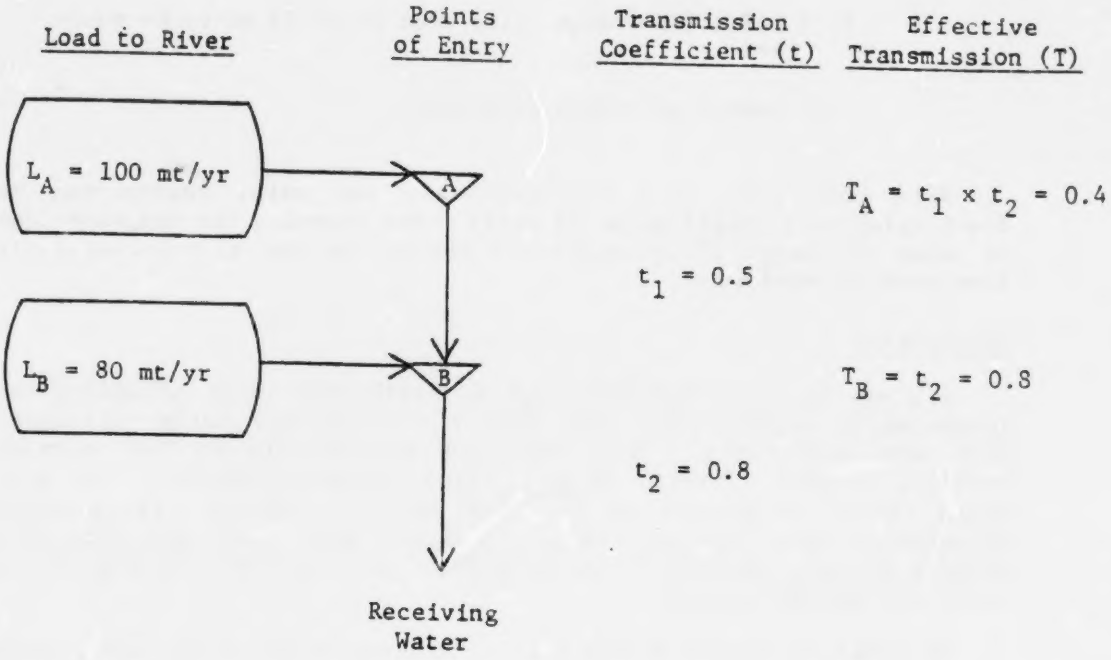
The load at the river mouth (or some point of entry) is expressed mathematically below.

Pollutant Load at the Lake =

$$\sum_{i=1}^{N} [(L_i \times BF)_{\text{cropland}} + (L_i \times BF)_{\text{rural non-cropland}} + (L_i \times BF)_{\text{urban land}} + (L_i \times BF)_{\text{point source}} \ldots + (L_i \times BF)_{\text{other sources}}] \times T_i \qquad (3)$$

FIGURE 2

EXAMPLE OF TRANSMISSION LOSS CALCULATION


Load to River
Points of Entry
Transmission Coefficient (t)
Effective Transmission (T)
L_A = 100 mt/yr
A
$T_A = t_1 \times t_2 = 0.4$
$t_1 = 0.5$
L_B = 80 mt/yr
B
$T_B = t_2 = 0.8$
$t_2 = 0.8$
Receiving Water

$$L_{RW} = (L_A \times T_A) + (L_B \times T_B)$$
$$= (100 \times 0.4) + (80 \times 0.8) = 104 \text{ mt/yr}$$

where L_A = Total Pollutant Load to Point of Entry A
L_B = Total Pollutant Load to Point of Entry B
L_{RW} = Total Pollutant Load to Receiving Water

If control strategy reduces the L_A by 50% (i.e., 50 mt/yr), then the new load (L_{RW_1}) is

$$L_{RW_1} = (50 \times 0.4) + (80 \times 0.8) = 84 \text{ mt/yr}$$
$$L_{RW} - L_{RW_1} = 104 - 84 = 20 \text{ mt/yr}$$

$\therefore$ a 50 mt/yr reduction to entry point A produces only a 20 mt/yr reduction at the receiving water where: L = loads from different sources to a specific point of entry,

BF = Bioavailability Factor,

T_i = Effective transmission from point of entry to mouth, and

N = number of points of entry.

Note that more than one sub-basin and point source may be discharging to a single point of entry. For example, the cropland load to point of entry "i" in equation 3 may be the sum of cropland loads from several sub-basins.

Calibration

One way in which WATERSHED can be calibrated is by adjusting the transmission coefficients such that the calculated loads correspond with monitored loads. This was done successfully in the overview modeling project (Johnson et al., 1978) discussed earlier. In most cases (about 75 percent of the time for U.S. waters), transmission adjustments were not necessary. However, when they were necessary (mainly for Lake Michigan), an impoundment or lake-like widening of the river was usually present.

In order to account for year-to-year differences in pollutant loads from a river basin caused by meteorological or climatic factors, loads estimated through WATERSHED should be calibrated with historical average monitored loads whenever possible. Calibration using data for any single year could be misleading if that year was a high- or low-flow year.

Sonzogni et al. (1978) have described a technique to adjust loads for any one year to "average" conditions. The technique is based on a historical average flow computed from gaging station records. Pollutant loads are then adjusted to average conditions in proportion to flow. The technique thus assumes that load is proportional to flow. This approach is most applicable on a gross scale and may not be appropriate for a small river basin. However, simply considering the range in annual flows can provide a qualitative appreciation of the variability expected in diffuse inputs due to meteorological (and runoff) conditions. This may often be sufficient for making WATERSHED management decisions.

In calibrating results, the transmission coefficient is not the only variable that can be adjusted. The values of a number of variables used in the process can be changed to more closely align the calculated load with the monitored load. Even if estimated loads from WATERSHED cannot be easily calibrated due to a lack of monitoring data, the results are still useful for assessing the relative importance of different pollutant inputs and for determining the sensitivity of the pollutant loads to different variables.

CONTROL STRATEGIES

Formulating Strategies

At this point, strategies to reduce pollutant loads can be developed. Of the different strategies identified for each source, one should be selected for initial testing. Other strategies may be evaluated in subsequent WATERSHED analyses. A strategy may be staged; that is, it may consist of one or more incremental control programs. Similarily, a control program may consist of one or more specific remedial measures.

A staged approach, whereby each program builds upon the previous one, is designed to allow for an incremental control strategy. For instance, a municipal point source control strategy for phosphorus might consist of three stages of chemical phosphorus control. Stages I, II and III might be treatment to the 1 mg/L, 0.5 mg/L and 0.3 mg/L phosphorus effluent levels, respectively. Stage III could not be implemented before Stage II, and Stage II could not be implemented before Stage I. However, it is possible that Stage I and II point source control programs should be implemented before either a Stage I cropland or Stage I urban runoff control program.

The flexibility of WATERSHED also permits the user to design a remedial program that is comprised of several different specific control measures, only some of which would be used at a specific site. In combination, the control measures would provide an average level of pollutant reduction at an average cost. Such a combination of control measures is likely to be needed for treating runoff in a sub-basin, since "across-the-board" runoff control programs are more the exception than the rule. For example, to decrease the pollutant contribution from a cropland area, several different tillage variations may be used on individual farms in the area, depending on factors such as the farmer's preference, type of cropland, and the site-specific characteristics of the land.

It should be apparent that considerable judgment is required in formulating strategies on control programs that are tailored to individual situations. It is important that the water quality manager be familiar with the control measures selected for each strategy and know how the controls relate to one another.

Costs and Load Reductions

In estimating the costs of and pollutant load reductions achieved from various control programs, only general guidelines can be given. The planner's or manager's judgment and experience is an important part of the process. Studies being conducted should soon provide more information on the cost and effectiveness of controls. The authors intend to provide a more detailed assessment of this topic in future work. In the meantime, the information given below (predominately on phosphorus) summarizes much of the current research. The information will be applied in the companion case study (Monteith et al., 1980).

Point Source: Various options for point source phosphorus control are given in Table 4. As explained in the previous section on formulating control strategies, some of the controls must be implemented in a hierarchical fashion. The load reduction achieved by these measures will depend on the phosphorus concentration before treatment. In the Great Lakes basin, the average phosphorus concentration in treated municipal wastewater from facilities with no phosphorus control program is about 4 mg/L P (Sonzogni *et al.*, 1978).

Costs for point source controls are perhaps better defined than controls for other pollution sources. Although municipal and industrial wastewater treatment plants use a variety of treatment processes, most have been used for a number of years and are well defined economically. Consequently, reasonable *cost estimates* can be made for most treatment schemes. Cost data may also be available from information developed under Section 208 of the Federal Water Pollution Control Act of 1972 and from information developed by the U.S. Environmental Protection Agency.

Urban Runoff Controls

Although many measures have been identified for controlling pollutant loadings from urban runoff (IJC, 1977), the cost and effectiveness of most have not been quantified. Table 5 does, however, provide some cost-effectiveness data developed for PLUARG. The U.S. Environmental Protection Agency is currently sponsoring the Nationwide Urban Runoff Program (NURP) which will determine the effectiveness and costs of various urban control practices. Initial results are expected within the year, although it may be another three years before the program is completed. This study is expected to provide an excellent source of information for use in WATERSHED. Studies done under Section 208 of the Federal Water Pollution Control Act of 1972 may also provide useful information, since they have focused on nonpoint source pollution during the last few years.

Rural Nonpoint Controls

Most control measures for rural land have focused on cropland, and these, rather than controls for rural non-cropland areas, are considered here.

One of the main reasons for relating cropland loads to potential gross erosion as calculated from the USLE is the available information on how control measures affect potential gross erosion. In particular, an extensive literature exists on how control measures such as tillage practices and crop rotation affect the cover factor (C). Some information also exists on how measures such as contour plowing and strip-cropping will affect the practice factor (P) and how terracing can affect the slope/length factor (SL).

Table 6 provides data for several cropland control programs according to some of the recent findings of studies such as the Lake Erie Wastewater Management Study (Urban *et al.*, 1978), the Black Creek

TABLE 4

COSTS OF PHOSPHORUS CONTROL AT MUNICIPAL WASTEWATER TREATMENT PLANTS

CONTROL PROGRAM	COST ($/cap/yr)
1. Reduction of total phosphorus effluent concentration from a "no phosphorus treatment" condition (∿ 4 mg/L) to 1.0 mg/L by chemical treatment[a]	2.4
2. Reduction of total phosphorus effluent concentration from 1 mg/L to 0.5 mg/L by chemical treatment[b]	3.6
3. Reduction of total phosphorus effluent concentration from 0.5 mg/L to 0.3 mg/L by chemical treatment/filtration[a]	4.0
4. Land treatment by rapid infiltration[c]	--
5. Land treatment by slow rate irrigation[c]	--

---

[a] Estimate derived from Drynan (1978).

[b] Estimate derived from Heidtke *et al.* (1979).

[c] Because all other costs assume conventional secondary treatment facilities in place, comparative costs of land application systems are not presented here; for further discussion see Heidtke *et al.* (1980).

TABLE 5

COSTS AND TOTAL PHOSPHORUS LOAD REDUCTIONS FOR URBAN RUNOFF CONTROL PROGRAMS[a]

CONTROL PROGRAM	URBAN DIFFUSE SOURCES							
	COMBINED SEWERED AREAS		SEPARATE SEWERED AREAS					
			HIGH INDUSTRY		MEDIUM INDUSTRY		LOW INDUSTRY	
	% UAL Reduction	$\$/km^2/yr$	% UAL Reduction	$\$/km^2/yr$	% UAL Reduction	$\$/km^2/yr$	% UAL Reduction	$\$/km^2/yr$
Streetsweeping plus Measures to Reduce Flow	6	7,400	20	7,400	25	7,400	50	7,400
Streetsweeping plus Detention/Sedimentation of Stormwater and Combined Sewer Overflows	30	32,100	40	16,000	45	16,000	65	16,000

---

[a] Adapted from Table 11, Johnson *et al.* (1978).

TABLE 6

COSTS AND LOAD REDUCTIONS

FOR RURAL RUNOFF PHOSPHORUS CONTROL PROGRAMS

CONTROL PROGRAM	RURAL DIFFUSE SOURCE					
	CROPLAND				OTHER AGRICULTURAL LAND	
	% Reduction in Potential Gross Erosion[a]	Pollutant Reduction Efficiency[b]	% Reduction in Total Phosphorus Load	$/km^2/yr	% Reduction in Total Phosphorus Load	$/km^2/yr
Voluntary Sound Land Management[c]	--	--	0-10	Minimal	0-10	Minimal
Chisel Plowing; Mulch-Till; Winter Cover Crops; Crop Rotations	50-60	.6-.9	30-55	65[d]	--	--
No-Till; Crop Rotations	60-90	.6-.9	35-80	3,000[e]	--	--

[a] Based on changes in average county "C" factors (crop management factor in the USLE) as given in Urban et al. (1978). Percent reductions assume all other USLE variables remain fixed.

[b] Estimate of the extent that the phosphorus load is decreased from a given decrease in gross erosion; values derived from LEWMS Preliminary Feasibility Report (U.S. Army Crops of Engineers, 1979).

[c] These measures (properly incorporating fertilizers into soils; avoiding farming on slopes near streams) may not affect erosion in cropland areas.

[d] Estimated cost of providing technical assistance and demonstration plots for education in new tillage practices.

[e] Cost estimate derived from U.S. EPA (1979) -- a modeling study of the Black Creek watershed in northeastern Indiana.

Study (Beasley et al., 1977) and the PLUARG study (PLUARG, 1978). Losses in potential gross erosion are based on changes in the "C" factor due to tillage or crop rotation practices.

Note that the first control program -- "voluntary sound land management" -- does not show an associated reduction in potential gross erosion. This program includes measures, such as properly incorporating fertilizer into the soil, which may have little effect on potential gross erosion.

For the second program in Table 6 (chisel-plowing, mulch-till, winter cover crops, crop rotations), the cost is based primarily on technical assistance. Technical assistance as defined here includes the operation of several demonstration plots to illustrate the effectiveness of the new practices. Although research continues on this subject, it is assumed here that this set of measures can be implemented with no net loss of income to the farmer. The only cost, therefore, is the technical assistance required to train farmers in new tillage methods. The Black Creek (Indiana) and Honey Creek (Ohio) demonstration programs have shown how important technical assistance is for these measures to be effective. Technical assistance would likely only be required for a short time (three to five years), since farmers would tend to share their experience with other farmers in the area if it is successful.

In calculating the technical assistance program, it is assumed that three years of demonstration and intensive assistance would be sufficient to convince farmers to adopt the proposed measures. It is also assumed that the technical assistance program would affect about 35,000 ha.

Table 7 further illustrates how costs for technical assistance were derived. Salary and overhead, demonstration plot costs and equipment rental costs are all estimated. The total cost is amortized over 25 years at a 10 percent interest rate to give an annual cost of $23,000. If this cost is converted to a unit area basis, the annual cost is $0.65/ha ($65/km^2) assuming 35,000 acres are actually influenced by the technical assistance. It is possible, for example, that up to 200,000 ha would be influenced at the above cost. If that were the case, the cost of technical assistance would be reduced to $0.12/ha.

The above costs were generated for the northwestern Ohio area, based on preliminary data for this area (Honey Creek Joint Board of Supervisors, 1980; U.S. Environmental Protection Agency, 1979). The cost estimate is admittedly only a first approximation, and is likely to be modified when better data become available.

The third program in Table 6 involves the application of more intensive conservation tillage practices (i.e., no-till where soils will allow it). The percent reduction in total phosphorus loading from cropland runoff -- 85 percent -- was also indirectly estimated from changes in "C" factors specified for northwestern Ohio by the U.S. Army Corps of Engineers (1979). The estimated incremental cost for implementing Stage II control is $3,000/km^2/yr (U.S. Environmental Protection Agency, 1979).

TABLE 7

ESTIMATION OF TECHNICAL ASSISTANCE COSTS FOR IMPLEMENTING THE MINIMUM TILLAGE AND CROP ROTATION PROGRAM

- 125 ha of demonstration plots
- 3-year program
- Goal of 35,000 ha converted to minimum till

- Salary and overhead	$ 38,500/yr
- Demonstration Plot Costs	$ 25,000/yr
- Equipment rental	$ 6,500/yr
TOTAL:	$ 70,000/yr

- 3-year study TOTAL	$210,000
- 10% interest amortized over 25 years	$ 23,000/yr
- Cost per ha considering only demonstration plots $23,000/yr ÷ 125 ha	$ 184/ha-yr
- Cost per ha if 35,000 ha converted to minimum till $23,000/yr ÷ 35,000 ha	$ 0.65/ha

Pollutant Reduction Efficiency

A pollutant such as phosphorus may not be reduced to the same extent as potential gross erosion following implementation of a control measure. Some control measures could conceivably result in a large change in potential gross erosion with little change in pollutant load. To account for this, a new term, the "Pollutant Reduction Efficiency" (PRE), is introduced in Table 6. The pollutant reduction efficiency is defined as the extent that a pollutant load (yield) is decreased from a given decrease in potential gross erosion.

In order to calculate the effect of pollution reduction efficiency on the load, the following equation is used:

$$L_R = L_I - [(E_I - E_R) \times PRE \times PDR] \tag{4}$$

where:

L_R = reduced pollutant load (due to runoff controls),

L_I = initial pollutant load,

E_I = initial potential gross erosion,

E_R = reduced potential gross erosion,

PRE = pollutant reduction efficiency, and

PDR = pollutant delivery ratio.

The use of equation 4 will be demonstrated in the case study companion paper.

According to studies of conservation tillage in the Lake Erie basin, the relationship between potential gross erosion and phosphorus load as affected by cropland runoff control programs can only be estimated. However, based on limited information, the decrease in phosphorus yield from a given decrease in potential gross erosion appears to be between 60 to 90 percent (U.S. Army Corps of Engineers, 1979). More research will have to be done on this subject in order to expand the usefulness of the USLE as a water quality management tool.

Control measures may also have varying effects on the bioavailable fraction of a given pollutant. For example, two measures may cause identical decreases in the total phosphorus load but different decreases in the available phosphorus fraction. This could result from one measure having a greater effect on the soluble phosphorus fraction. The difference would have to be accounted for in the bioavailability factor in the WATERSHED process.

Presently, almost no field data exist on how control measures might affect bioavailability. About the best that can be done is to use sound judgment, tempered with a knowledge of how the control measure may effect the chemistry of the pollutant.

Substantial new information on the cost-effectiveness of cropland runoff control measures is expected soon, especially with regard to the economics of conservation tillage practices. With rising fuel costs, many farmers may find it desirable to convert to a conservation tillage system, making the implementation of these systems easier than originally anticipated. Further, preliminary results from the Lake Erie Wastewater Management Study's Honey Creek Demonstration Project (Forester et al., 1977; Forester, 1978; Honey Creek Joint Board of Supervisors, 1980) show that costs can be reduced and farm productivity may actually be increased if farmers in that area adopt no-till farming. The net result could be an increased profit for farmers and a concomitant reduction in the nonpoint loads from their farm lands.

It should be clear that Tables 4, 5 and 6 are only examples of programs that can be formulated. Options other than those given here may be appropriate for a certain location. The tables do illustrate the type of cost and pollutant reduction information that is necessary to characterize a control option or program.

Cost Effectiveness

The goal of WATERSHED is to compare the cost-effectiveness (cost per unit reduction in pollutant load) of reducing pollution from different point and nonpoint sources in a basin. The option with the lowest cost per unit reduction in pollutant load is the most cost-effective.

For comparison purposes, cost-effectiveness is generally best measured at the receiving water (river mouth). Once the cost-effectiveness at the receiving water is known for each stage of a control strategy developed for a particular pollutant source, the stages of the strategy can be ranked according to their cost-effectiveness. For example, if a control strategy with three stages of control were devised for each of ten pollutant sources in a river basin, a total of 30 different control stages could be ranked.

Note that each staged program of a strategy can consist of either one control measure or a combination of control measures. For a given strategy, Stage II can never be ranked higher than Stage I, Stage III can never be ranked higher than Stages I or II, and so forth, due to the dependence of a stage on previous stages. However, a Stage II point source control could be ranked higher than a Stage I cropland control. In other words, WATERSHED allows for comparing different stages of point and non-point control strategies.

Accounting Techniques

To simplify tracking all the inputs and load reductions, and to ultimately rank the cost-effectiveness of different strategies, some kind of an accounting system is needed. While a computerized accounting system has been developed, a system of worksheets has recently been devised which clearly shows how to apply the WATERSHED process. This approach can be used efficiently with a calculator. A programmable calculator could simplify the accounting process even more.

The worksheets are straightforward yet flexible, and are somewhat analogous to an income tax form. Their use is demonstrated in a case study of the Sandusky River (Ohio) in the companion paper by Monteith et al. (1980).

Long-Term Value of WATERSHED

A major advantage of the WATERSHED process is that it can accommodate a large and dynamic data base. As criteria change or new detailed information becomes available on such factors as effectiveness of control programs or the costs of remedial programs, WATERSHED may be used to reevaluate which pollution control programs offer the best results for the tax dollar. Once the river drainage basin has been mathematically described and the loads from all the pollutant sources mathematically defined, the basic information exists to test any assortment of remedial strategies or to determine the sensitivity of the results to a modification of a given variable. Thus, the WATERSHED analysis is a planning tool which will have many applications and will form the basis for long-term river basin management.

Multiobjective Analysis

Currently, the WATERSHED process considers only one pollutant at a time. However, it is recognized that control strategies may, in fact, affect more than one pollutant. For example, removing phosphorus at a municipal wastewater treatment plant may concurrently reduce discharges of biochemical oxygen demand, suspended solids, toxic metals and viruses. Ideally, a multiobjective analysis should be performed so that the cost of the total phosphorus control program could be evaluated against benefits (or costs) other than just those associated with phosphorus reductions. Simon (1980) has made an initial attempt at this by modifying the overview modeling approach of PLUARG (discussed earlier) with a parametric nonlinear optimization technique. Consequently, he was able to consider the control of several pollutants. Further, Chapra and Wicke (1980) have made some initial steps in this direction. The authors intend to address multiobjective analysis in upcoming work.

Load Allocations

If a load limitation has been imposed on a particular river basin, WATERSHED can be used to determine the most cost-effective combination of strategies to achieve the desired pollutant load. However, in very few cases have pollutant loads been allocated to river basins. Even in the Great Lakes basin, where so-called "target loads" have been suggested for the individual lakes, there has been no attempt to allocate portions of the lake loads between the U.S. and Canada, let alone individual river basins.

Although load objectives may not exist for a river basin, the planner or manager may want to consider what control strategies should be given priority because they produce high load reductions at low cost. Such strategies would be implemented to reduce pollution in general, rather than to achieve a certain allocated load. WATERSHED can, of course, be a very useful tool for the planner or manager in this situation.

If water quality improvements are to be made in increments, WATERSHED can, based on its cost-effectiveness ranking, show which measures should be done first. The planner or manager must rely on information other than WATERSHED, since control measures will have benefits and costs other than those considered in WATERSHED. For example, many nonpoint control measures improve soil conservation as well as water quality. Consequently, some nonpoint control measures should perhaps be implemented as a soil conservation measure even though it has little effect on water quality.

As mentioned above, so-called target loads for phosphorus have been suggested for the Great Lakes. However, as discussed in Sonzogni et al. (1979), these loads are best used only as long-term goals. It is better to make water quality improvements step by step, based on economic as well as environmental considerations. One rationale for this approach is that water quality degradation is often reversible, so that receiving waters often are not irreversibly harmed if all pollutant inputs are not immediately controlled. This is especially evident in the way lakes have responded to phosphorus input reductions. The effects of some toxic substances (for example, DDT) have also been shown to be reversible (Sonzogni and Swain, 1980). The reversible nature of water quality degradation is of great significance to management, particularly when funds for pollution control are limited.

REFERENCES

Beasley, D.B., Monke, E.J., and L.F. Huggins (1977). "The ANSWERS Model: A Planning Tool for WATERSHED Research," American Society of Agricultural Engineers, Paper No. 77-2532, St. Joseph, Mich.

Chapra, S.C., and H.D. Wicke (1980). "Least Cost Optimization to Meet Phosphorus Objectives in the Lower Great Lakes," Contribution to the Great Lakes Environmental Planning Study from the Great Lakes Environmental Research Laboratory (NOAA), Draft.

Chesters, G., Konrad, J.G., and G.V. Simsiman (1980). "Menomonee River Pilot WATERSHED Study - Summary and Conslusions," Draft Report, University of Wisconsin Water Resources Center, Madison, Wisconsin, 77 pp.

Drynan, W.R. (1978). "Relative Costs of Achieving Various Levels of Phosphorus Control at Municipal Wastewater Treatment Plants in the Great Lakes Basin," International Joint Commission, Great Lakes Regional Office, Windsor, Ontario.

Forester, L.D. (1978). "Economic Impact of Changing Tillage Practices in the Lake Erie Basin," U.S. Army Corps of Engineers, Buffalo District, Buffalo, New York.

Forester, L.D., and G.S. Becker (1977). "Economic and Land Management Analysis in Honey Creek Watershed," U.S. Army Corps of Engineers, Buffalo District, Buffalo, New York.

Heidtke, T.M. (1979). "Modeling the Great Lakes System: Update of Existing Models," Great Lakes Environmental Planning Study Contribution No. 4, Great Lakes Basin Commission, Ann Arbor, Michigan, 79 pp.

Heidtke, T.M., Monteith, T.J., Sullivan, R.A., Scheflow, D.J., Skimin, W.E., and W.C. Sonzogni (1979). "Future U.S. Phosphorus Loadings to the Great Lakes: An Integration of Water Quality Management Planning Information," Great Lakes Environmental Planning Study Contribution No. 11, Great Lakes Basin Commission, Ann Arbor, Michigan, 71 pp.

Heidtke, T.M., Scheflow, D.J., and W.C. Sonzogni (1980). "U.S. Heavy Metal Loadings to the Great Lakes: Estimates of Point and Nonpoint Contributions," Great Lakes Environmental Planning Study Contribution No. 12, Great Lakes Basin Commission, Ann Arbor, Michigan, 34 p.

Heidtke, T.M., and W.C. Sonzogni (1979). "Modeling the Great Lakes System: Ongoing and Planned Modeling Activities," Great Lakes Environmental Planning Study Contribution No. 6, Great Lakes Basin Commission, Ann Arbor, Michigan.

Heidtke, T.M., Sonzogni, W.C. and T.J. Monteith (1979). "Management Information Base and Overview Modeling: Update of Projected Loadings to the Great Lakes," Great Lakes Environmental Study Contribution No. 7, Great Lakes Basin Commission, Ann Arbor, Michigan, 38 p.

Heidtke, T.M., Scheflow, D.J., and W.C. Sonzogni (1980). "Comparative Cost-Effectiveness of Land Application of U.S. Municipal Wastewater: Implications for Phosphorus Control in the Great Lakes Basin," Great Lakes Environmental Planning Study Contribution No. 19, Great Lakes Basin Commission, Ann Arbor, Michigan, 34 p.

Honey Creek Joint Board of Supervisors (1980). "Honey Creek Watershed Project Tillage Demonstration Results 1979," U.S. Army Corps of Engineers, Buffalo District, Buffalo, New York.

International Joint Commission (IJC) (1977). "Evaluation of All Remedial Measures to Control Nonpoint Sources of Water Pollution in the Great Lakes Basin," Great Lakes Regional Office, Windsor, Ontario.

International Joint Commission (IJC) (1976). "Great Lakes Water Quality Board, Appendix B, Surveillance Subcommittee Report," Great Lakes Regional Office, Windsor, Ontario.

Johnson, M.G., Comeau, J.C., Heidtke, T.M., Sonzogni, W.C., and B.W. Stahlbaum (1978). "Management Information Base and Overview Modeling," prepared for the Pollution from Land Use Activities Reference Group (PLUARG), International Joint Commission, Windsor, Ontario, 90 pp.

Johnson, M.G., Comeau, J.C., Heidtke, T.M., Sonzogni, W.C., and B.W. Stahlbaum (1980). "Modeling Effects of Remedial Programs to Aid Great Lakes Environmental Management," J. Great Lakes Res., 6 (1), p.8-21.

Jones, R.A., and G.T. Lee (1979). "Septic Tank Wastewater Disposal Systems as Phosphorus Sources for Surface Waters," Journal WPCF, 51, 11, p.2764-2775.

Knisel, W.G., ed. (1980). "CREAMS, A Field-Scale Model for Chemicals, Runoff and Erosion from Agricultural Management Systems," U.S. Department of Agriculture, Conservation Research Report No. 26, 640p.

Krause, A. and J.R. Pilling (1979). "Alternative Waste Treatment Systems for Rural Lake Projects," U.S. Environmental Protection Agency, Region V, Draft.

Marsalek, J. (1978). "Pollution Due to Urban Runoff: Unit Loads and Abatement Measures," National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ontario.

McElroy, A.D., Chin, S.Y., Nebgen, J.W., Aleti, A., and F.W. Bennett (1976). "Loading Functions for Assessment of Water Pollution from Nonpoint Sources," U.S. Environmental Protection Agency, Environmental Protection Technology Series Report No. 600/2-76-151, Washington, D.C.

Monteith, T.J., and E.A. Jarecki (1978). "Land Cover Analysis for the United States Great Lakes Watersheds," Great Lakes Basin Commission for the International Joint Commission, Windsor, Ontario.

Monteith, T.J., Sonzogni, W.C., Heidtke, T.M., and R.A.C. Sullivan (1980). "WATERSHED - A Management Technique for Choosing Among Point and Nonpoint Control Strategies. Part 2 - A River Basin Case Study," Great Lakes Basin Commission, Ann Arbor, Michigan.

Novotny, V., Balsiger, D., Cherkauer, D.S., Simsiman, G.V., Chesters, G., Bannerman, R., and J.G. Konrad (1979). "Simulation of Pollutant Loadings and Runoff Quality," Menomonee River Pilot Watershed Study, University of Wisconsin Water Resources Center, Madison, Wisconsin.

Pollution from Land Use Activities Reference Group (PLUARG) (1978). "Environmental Management Strategy for the Great Lakes System," International Joint Commission, Windsor, Ontario, 115 p.

Reckhow, K.H., Beaulac, M.N., and J.T. Simpson (1980). "Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients," Draft Report to the U.S. Environmental Protection Agency, Department of Resource Development, Michigan State University, East Lansing, Michigan, 214 p.

SEMCOG (1978). "Regional Evaluation of a Phosphorus Detergent Ban," Southwestern Michigan Council of Governments, Detroit, Michigan.

Simon, D.P. (1980). "A Parametric Nonlinear Optimization Approach to the Water Quality Problems of Southeastern Wisconsin," Draft Report, University of Wisconsin Water Resources Center, Madison, Wisconsin.

Sonzogni, W.C., Chapra, S.C., Armstrong, D.E., and T.J. Logan (1980). "Phosphorus Availability - Significance to Modeling and Management," in preparation.

Sonzogni, W.C., Jeffs, D.N., Konrad, J.C., Robinson, J.B., Chesters, G., Coote, D.R., and R.C. Ostry (1980). "Pollution from Land Runoff," Envir. Sci. and Tech., 14(2), p. 148-153.

Sonzogni, W.C., Monteith, T.J., Bach, W.N., and V.G. Hughes (1978). "United States Great Lakes Tributary Loadings," Great Lakes Basin Commission for the International Joint Commission, Great Lakes Regional Office, Windsor, Ontario.

Sonzogni, W.C., Monteith, T.J., and T.M. Heidtke (1979). "Proposed Great Lakes Phosphorus Target Loads: A Synopsis and Some Perspectives," Great Lakes Environmental Planning Study Contribution No. 5, Great Lakes Basin Commission, Ann Arbor, Michigan, 9p.

Sonzogni, W.C., Monteith, T.J., Skimin, W.E., and S.C. Chapra (1979). "Critical Assessment of U.S. Land Derived Pollutant Loadings to the Great Lakes," Task D Report, Pollution from Land Use Activities Reference Group, International Joint Commission, Windsor, Ontario.

Sonzogni, W.C., and W.R. Swain (1980). "Perspectives on U.S. Great Lakes Chemical Toxic Substances Research," J. Great Lakes Res., in press.

Stewart, B.A., Woolhiser, D.A., Wischmeier, W.H., Caro, J.H., and M.H. Frere (1975). "Control of Water Pollution from Cropland - Volume 1, A Manual for Guideline Development," Agricultural Research Services Report No. ARS-H-5-1, U.S. Department of Agriculture, Hyattsville, Maryland, 111p.

Sullivan, R.A., Sanders, P.A., and W.C. Sonzogni (1980a). "An Update of Water Quality Planning Activities in the U.S. Great Lakes Basin - Review of State and Areawide Agency Five Year Strategies and Work Programs," Great Lakes Basin Commission for the Great Lakes National Program Office, U.S. Environmental Protection Agency.

Sullivan, R.A., Sanders, P.A., and W.C. Sonzogni (1980b). "Post-PLUARG Evaluation of Great Lakes Water Quality Management Studies and Programs," Great Lakes Basin Commission for the Great Lakes National Program Office, U.S. Environmental Protection Agency.

Sullivan, R.A.C., Scheflow, D.J., and W.C. Sonzogni (1980). "The Relative Significance of U.S. Industrial Heavy Metal Loads to the Great Lakes," Great Lakes Environmental Planning Study Contribution No. 16, Great Lakes Basin Commission, Ann Arbor, Michigan, 42p.

Urban, D.R. (1980). Personal Communication, U.S. Environmental Protection Agency, Region V, Chicago, Illinois.

Urban, D.R., Logan, T.J., and J.R. Adams (1978). "Application of the Universal Soil Loss Equation in the Lake Erie Drainage Basin," U.S. Army Corps of Engineers, Buffalo District, Buffalo, New York.

U.S. Environmental Protection Agency (EPA) (1977). "Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Discharges Volume II: Cost Assessment and Impacts," EPA Report No. 600/2-77-064.

U.S. Environmental Protection Agency (EPA) (1979). "Costs and Water Quality Impacts of Reducing Agricultural Nonpoint Source Pollution," Office of Research and Development, Athens, Georgia.

U.S. Army Corps of Engineers (1975). "Urban Stormwater Runoff - STORM," The Hydrologic Engineering Center, Davis, California.

U.S. Army Corps of Engineers (1979). "Lake Erie Wastewater Management Study Methodology Report," Buffalo District, Buffalo, New York, 146p.

Verhoff, F.H., Melfi, D.A., Yaksich, S.M., and D.B. Baker (1978). "Phosphorus Transport in Rivers," U.S. Army Corps of Engineers, Buffalo District, Buffalo, New York.

Wischmeier, W.H., and D.D. Smith (1978). "Predicting Rainfall Erosion Losses," Agricultural Handbook No. 537, Science and Education Administration, U.S. Department of Agriculture, Washington, D.C.

RECAP OF PREVIOUS DAY'S PROGRAM
AND
GOALS FOR TODAY

BY
CARL D. WILSON*

I WOULD LIKE TO REMIND THE AUDIENCE TO REGISTER AND GIVE THEIR ADDRESS IF YOU WISH TO RECEIVE A COPY OF THE SEMINAR PROCEDURES ON "WATER QUALITY MANAGEMENT TRADE OFFS."

I WOULD LIKE TO REPEAT THE OBJECTIVE OF THIS SEMINAR WHICH IS TO PRESENT A METHODOLOGY TO EVALUATE NONPOINT AND POINT SOURCE POLLUTION IN ORDER TO TREAT THE SOURCE OF THE LOADS IN A COST-EFFECTIVE MANNER. TO DATE, THE ENVIRONMENTAL PROTECTION AGENCY HAS APPLIED ITS EFFORTS TO POINT SOURCE POLLUTION ONLY.

WE ORIGINALLY STARTED THE NONPOINT SOURCE PROGRAM IN 1971 BY DEVELOPING THE BLACK CREEK PROJECT IN ALLEN COUNTY, INDIANA. "BEST MANAGEMENT PRACTICES" WERE APPLIED ON A 12,000 ACRE WATERSHED WHICH WAS PLANTED WITH CORN AND SOYBEANS, WHICH ALSO INCLUDED EXTENSIVE AUTOMATED WATER SAMPLERS. AFTER DATA WAS COLLECTED WE INITIATED SEMINARS TO LET THE PUBLIC KNOW OF THE ANALYTICAL RESULTS. THE SECTION 108 PROGRAM OF THE GREAT LAKES NATIONAL PROGRAM OFFICE IS THE ORIGINAL SOURCE OF FUNDING FOR NONPOINT SOURCE PROGRAMS, SEMINARS AND WORKSHOPS.

OUR OBJECTIVE, THEN AS IS NOW, IS TO DEVELOP A METHODOLOGY TO EVALUATE BEST MANAGEMENT PRACTICES AS THEY EFFECT WATER QUALITY. IN OTHER WORDS GIVE THE CAUSE AND EFFECT IN A QUANTIFIED MANNER.

IN THE PAST THE CONSTRUCTION GRANTS PROGRAM USUALLY OBTAINED THE NONPOINT SOURCE LOAD BY SUBSTRACTION. IN OTHER WORDS THEY ADDED UP POINT SOURCE LOADS COMING OUT OF A PIPE AND SUBSTRACTED THAT NUMBER FROM THE TOTAL RIVER LOAD TO OBTAIN NONPOINT LOADS. WELL AT THE TIME THAT WAS SUFFICIENT. BUT WE HAVE ARRIVED AT A POINT WHERE THAT SYSTEM IS NOT ACCEPTABLE. WHY? WE CANNOT MEET OUR WATER QUALITY GOALS IN A COST-EFFECTIVE MANNER WITH THIS PROCEDURE. THUS WE MUST DEVELOP A NEW SYSTEM THAT IS MORE EQUITABLE AND EFFECTIVE.

OF COURSE PUBLIC LAW 92-500 HAD A SECTION CALLED 208 AND UNDER THIS SECTION OF THE LAW, STATES AND AREAWIDE AGENCIES DEVELOPED 208 PLANS TO ADDRESS ALL SOURCES OF POLLUTION AND DEVELOP A PLAN THAT CAN BE IMPLEMENTED TO MEET WATER QUALITY GOALS. PART OF THESE PLANS INCLUDE THE CONSTRUCTION OF SEWAGE TREATMENT PLANTS WHERE EPA HAS PUT BILLIONS INTO THIS PROGRAM. AND AT THE SAME TIME EPA WAS PUBLISHING DATA SAYING, IN FACT, WE WOULD NOT MEET OUR WATER QUALITY GOALS UNLESS WE TREATED NONPOINT SOURCE POLLUTION. SO WHAT IS THE ANSWER? THE SEMINAR WILL PRESENT A METHODOLOGY TO RESOLVE THE PROBLEM. FIRST A FEW COMMENTS ON MODELING.

*CARL D. WILSON IS A NONPOINT SOURCE COORDINATOR FOR REGION V, EPA. PRESENTATION GIVEN AT THE PICK CONGRESS HOTEL, CHICAGO, ILLINOIS SEPTEMBER 17, 1980. SEMINAR ON WATER QUALITY MANAGEMENT TRADE-OFFS.

To evaluate nonpoint source pollution the problem is approached from a watershed basis. At this point I am assuming the modelers are utilizing the "Standard Soil Survey" conducted by the United States Department of Agriculture. If the modelers are not using this soil survey in my opinion their models are totally useless to evaluate nonpoint source pollution from farm and ranch land. To further substantiate my point all tillage systems research are also based on the Standard Soil Survey, this includes management systems in general. Thus, all practices to control erosion and water quality have to relate to the same base to maintain production and protect water quality.

There are several models that are available and your selection of a model depends on the size of area you wish to investigate. The International Joint Commission, through their PLUARG studies, utilized a "Unit Area Load" approach and for generalized data this system can give program guidance. But to be more specific as to where the problem is you would have to select a model that is more site specific such as the ANSWERS model.

Thus to obtain even more detail on a farm size unit the CREAMS model would be your choice.

But in this seminar we wish to present a generalized methodology that can be solved with a desk calculator and it is called WATERSHED. Your comments on this methodology will be appreciated.

Now to briefly restate what the speakers said yesterday.

On water quality issues, Madonna McGrath of the Great Lakes National Program Office gave an overview which included phosphorus loads to the Great Lakes. She made the point there are some well developed methodologies and the need to be used.

Jeff Nedelman representing Senator Gaylord Nelson's office gave us a background on the environmental movement and restated the importance of setting goals. He expressed congressional concern over costs and suggested priorities could be a way to be more cost-effective in treating pollution. Also he reiterated their support for the phosphate detergent band. He also related how slow our system is to respond to correcting pollution problems. From his viewpoint there is a lack of sensitivity in Congress for pollution problems. EPA is not getting the money needed for the Great Lakes. Example EPA spent $13,000,000 on travel and only $2,000,000 on the Great Lakes. He also noted EPA estimates 54 billion dollars will be needed to complete the secondary treatment plants and advanced waste treatment projects.

Peter Wise from EPA headquarters Water Planning Division stated 208 planning had done a poor assessment of nonpoint source pollution. He also stated we need cause and effect data from nonpoint sources. Concerns were expressed about modeling. Plans need to be updated to correct deficiencies. Trade-offs between point and nonpoint are a problem. Some thoughts have been should we pay for nonpoint source controls? How to arrive at trade-offs is still a problem with the Agency.

Keith Young of the Soil Conservation Service gave an excellent presentation on prime agricultural land. My comment, we will see the day when a line will be drawn around prime agricultural land and that will be its sole use, agriculture.

Jeff Gagler of the Water Quality Policy Section-EPA gave an in depth look at advanced secondary treatment and advanced waste treatment (AST/AWT). He pointed problems in evaluation of point source vs. nonpoint. A background on water quality standards was covered, including water quality goals. He pointed out a need for classification guidelines which would also include biological systems. Concluded the whole economic picture needs to be reviewed.

Ronald Mustard of the Office of Environmental Review covered the issues concerning wetlands and floodplains. He gave a brief background on the law. Note agricultural drainage is 15% of the wetland problem according to a recent report.

Don Bundy of the International Joint Commission spoke about the U.S./Canada Great Lakes Water Quality Agreement and its impact on U.S. Policy. He restated the IJC boards major objective to restore the water quality of the Great Lakes. There have been major revisions in the water quality standards.

David Stringham, Regional Program Coordinator for Region V-EPA gave a presentation on the State/EPA Agreements. This is a method to work with the states to arrive at priorities to solve problems. And this would give guidance to future EPA programs.

William Benjey of the Water Quality Planning Branch gave an overview of water quality plans. He pointed out the problem of building sewage treatment plants and still not impacting water quality. Suggested integrating all sources of pollution before moving forward with treatment. He stated nonpoint source trade-offs are supposed to be considered in facility plans.

Mike MacMullen from the Water Quality Policy Section of EPA covered water quality standards. Reaffirmed EPA's commitment to water quality standards and goals. He also stated EPA will publish standards on 129 priority pollutants.

Leland McCable of EPA's Health Effects Laboratory gave the results from some current studies on epidemiology results from beach studies.

Ronald Drynan from the Regional Office of the International Joint Commission covered sources of pollutants to the Great Lakes. He stated the greatest source of totals loads comes from nonpoint source pollution. Point out we need to look at a mix between point source and nonpoint source loads.

Nelson Thomas of USEPA Research Laboratory described tributary loads and their effects on the Great Lakes. He stated there is a need to have management trade-offs between point source and nonpoint. Gave data on loads to the Great Lakes which included atmospheric loads of phosphorus. Spoke about the 11,000 metric ton load established for Lake Erie and which sources will have to be controlled to reach this agreed upon number. Food chain accumulation problem was discussed. Mirex, taste and odor problems were elaborated on.

Al Wallace from the Department of Civil Engineering, University of Idaho spoke about land treatment of municipal wastewater.

James Hanlon from EPA's Environmental Engineering Branch spoke on costs of wastewater treatment. There was $31.5 billion appropriated for sewage treatment plants.

William Sonzogni of the Great Lakes Basin Commission presented a proposed methodology to integrate point source and nonpoint source pollution assessment. My comment on this method or one similar will be used in the future for water quality management trade-offs.

WATER
SHED

A MANAGEMENT TECHNIQUE FOR
CHOOSING AMONG POINT AND NONPOINT CONTROL STRATEGIES

PART 2 - A RIVER BASIN CASE STUDY

for presentation at

U.S. EPA Region V Seminar on
WATER QUALITY MANAGEMENT TRADE-OFFS
September 16 and 17, 1980

by

Timothy J. Monteith
William C. Sonzogni
Thomas M. Heidtke
Rose Ann C. Sullivan

Great Lakes Basin Commission Staff

September, 1980

A MANAGEMENT TECHNIQUE FOR CHOOSING AMONG POINT AND NONPOINT CONTROL STRATEGIES

PART 2 - A RIVER BASIN CASE STUDY

by

Timothy J. Monteith, William C. Sonzogni,
Thomas M. Heidtke, and Rose Ann C. Sullivan*

Abstract: The WATERSHED management technique has been designed to help water quality managers select the most cost-effective pollution control program for a drainage area. WATERSHED has been applied to the Sandusky River Basin in northern Ohio to demonstrate how it is used and how to interpret the results. Programs to control total phosphorus loadings from point and nonpoint sources are evaluated using eight worksheets to compile the river basin data and carry out calculations. WATERSHED is applied in this manner: the river basin physical layout is conceptualized and all major total phosphorus sources are identified. Phosphorus loads from point sources, urban runoff, rural non-cropland runoff and cropland runoff are calculated for initial conditions and under different stages of control. Program costs are calculated and used to estimate the cost-effectiveness of each program. The forty programs identified are then prioritized according to their cost-effectiveness in reducing the total phosphorus load at the river mouth or receiving water.

---

* Great Lakes Basin Commission Staff. Water Resources Engineer, Water Resources Scientist, Water Resources Engineer, and Regional Planner/Policy Analyst, respectively. Great Lakes Basin Commission, Ann Arbor, Michigan.

INTRODUCTION

A companion paper (Sonzogni et al., 1980) discusses the philosophy and basic components of the WATERSHED process. This paper presents an application of WATERSHED to the Sandusky River in northern Ohio. The case study focuses on loadings of and control strategies for total phosphorus.

This case study is intended to demonstrate how WATERSHED may be applied to a river basin. It is not intended to serve as a rigorous analysis of point and nonpoint sources in the Sandusky basin. Some simplifications of the Sandusky field data have been made in order to better illustrate the process. If a detailed analysis of the Sandusky was required, individuals intimately familiar with the Sandusky River Basin would need to be consulted.

Eight different worksheets have been developed for compiling the river basin data and making the necessary calculations discussed in Sonzogni et al., 1980. These worksheets provide a simple, sequential procedure for assessing the importance of point and nonpoint sources in a river basin. The worksheets, in order of their use, are listed below:

1. Physical Layout
2. Point and Urban Runoff Loads
3. Rural Non-Cropland Loads
4. Cropland Loads
5. Loading Summary
6. Program Costs
7. Cost-Effectiveness Analysis
8. Program Summary

This paper illustrates: (1) how these worksheets are used in an actual river basin (i.e., the Sandusky River Basin), (2) the results which are obtained, and (3) how to interpret these results.

EXAMPLE STUDY AREA - SANDUSKY RIVER BASIN

The Sandusky River Basin was selected for this WATERSHED example because it contains a representative mix of rural and urban land. The phosphorus load contributed by this basin has also been extensively studied by the U.S. Army Corps of Engineers in their Lake Erie Wastewater Management Study (LEWMS) and by the Water Quality Laboratory at Heidelberg College. Hence, considerable data exist to test the results of the WATERSHED analysis.

The Sandusky River drains an area of about 400,000 hectares (980,000 acres) in northcentral Ohio. The Sandusky flows north to Lake Erie, draining mostly farmland. There are four cities of significant size (population greater than 6,000) that discharge both municipal wastewater and stormwater into the Sandusky: Bucyrus, Upper Sandusky, Tiffin and Fremont. For a detailed description of the Sandusky River system, see U.S. Army Corps (1975, 1979b).

PHYSICAL LAYOUT (WORKSHEET 1)

The first step in WATERSHED is to divide the Sandusky basin into sub-basins. The Sandusky has a well-defined monitoring network which provides excellent loading records from individual hydrologic areas. These stations monitor sub-basins that each have relatively homogeneous soils and land uses. The resulting sub-basins are shown in Figure 1.

The next step is to develop a schematic diagram of the watershed which delineates the key components along the river channel. Figure 1 and Worksheet 1 show how the Sandusky River Basin was divided for this example, both physically and schematically.

Points of Entry

As shown on Worksheet 1, six points of entry have been defined for the Sandusky River Basin (A-F). Each receives a total phosphorus load from one or more rural sub-basins. The urban runoff and point source contributions from the cities of Bucyrus, Upper Sandusky, Tiffin and Fremont are assumed to enter the main channel at points A, B, D and E, respectively.

The points of entry were selected after inspection of hydrologic maps and sampling station locations within the drainage area. In this way the estimated total phosphorus loads to the main channel from all sources can be compared with field measurements obtained from the ongoing sampling program. No major reservoirs, lakes or other significant physical influences were identified along the river system. If present, however, their locations would have also been considered in defining the points of entry for this example.

If transmission losses were not to be considered in a given section of the river channel, the number of points of entry could be reduced. For example, if it were known that no transmission losses occur between entry points A and C, rural positions 1, 3, 4, 6 and 7 as well as urban positions 2 and 5 could all be located at entry point C.

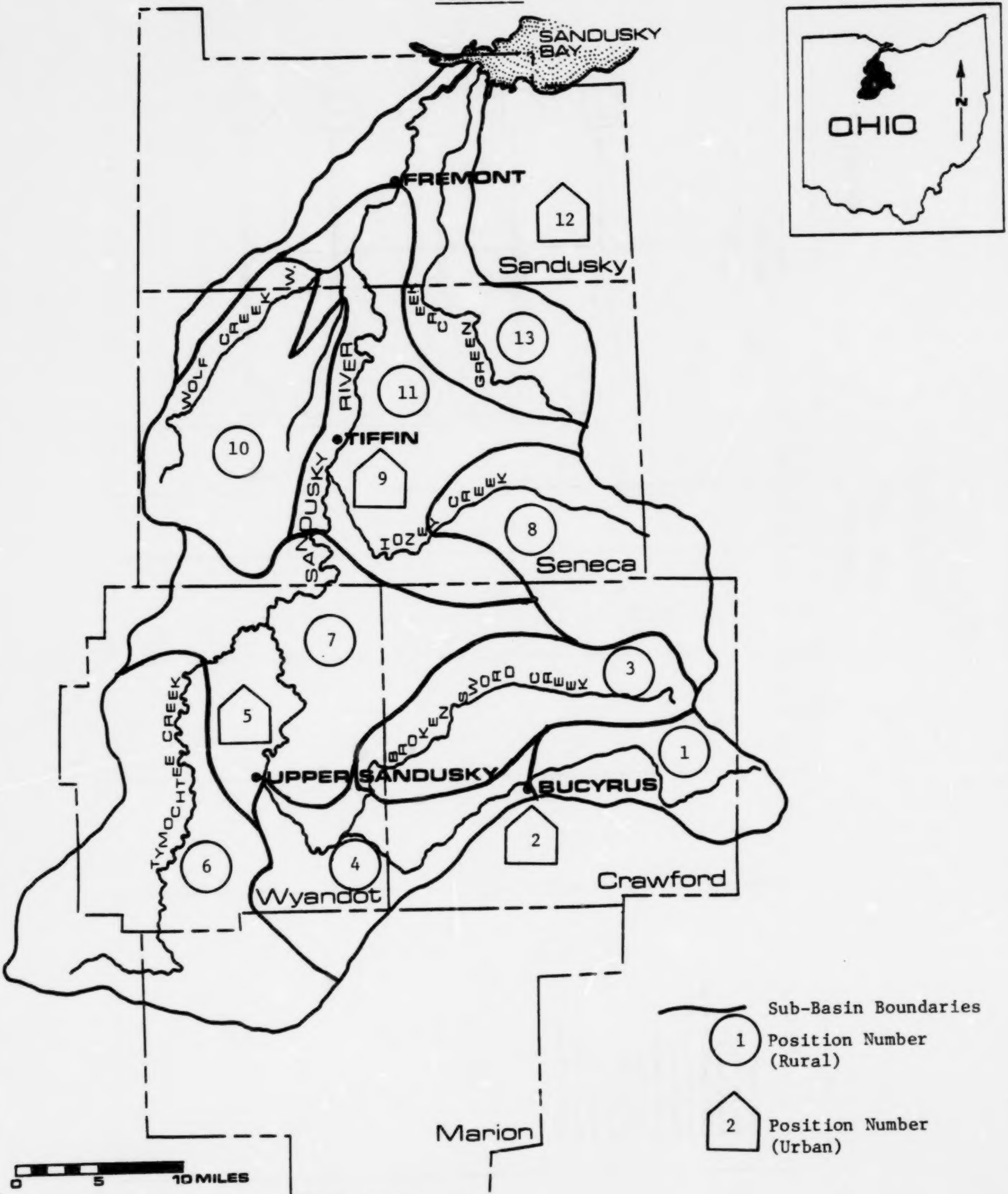
Control Strategies

In this case study, programs to reduce initial pollutant loads are evaluated. For each pollutant source, control programs are grouped into "stages" of implementation. Any number of stages can be selected for each pollutant source. For this example, two stages of control were considered for reducing the total phosphorus load from each major source (rural runoff, urban runoff and municipal point source discharges). The stages of control have been formulated as incremental levels of treatment. Thus, the costs and load reductions presented in the following worksheets for Stage II control are incremental (in addition to) the costs and load reductions associated with Stage I control.

This staged approach to control of total phosphorus loadings allows for a logical, straightforward examination of the level of treatment required at each source. Each additional stage represents an

Sandusky River, Ohio

FIGURE 1

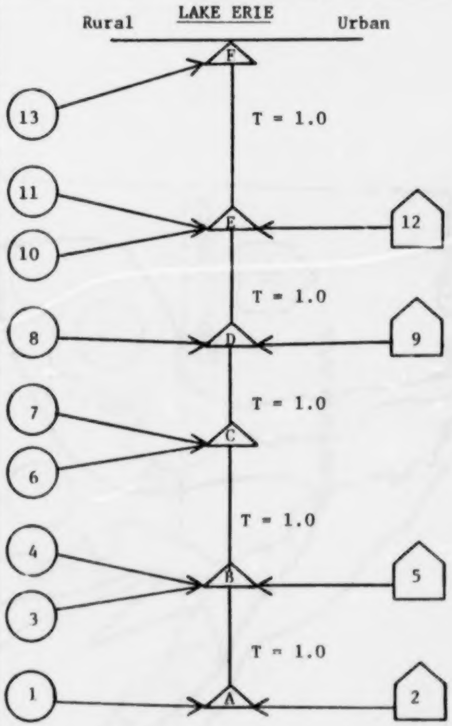

SANDUSKY BAY
OHIO
N
FREMONT
12
Sandusky
W. CREEK
WOLF CREEK
GREEN CREEK
13
RIVER
11
10
TIFFIN
9
SANDUSKY
HOZEY CREEK
8
Seneca
SANDUSKY
7
3
BROKEN SWORD CREEK
TYMOCHTEE CREEK
5
1
UPPER SANDUSKY
BUCYRUS
2
6
4
Wyandot
Crawford
Marion
Sub-Basin Boundaries
1 Position Number (Rural)
2 Position Number (Urban)
0
5
10 MILES

PHYSICAL LAYOUT

SANDUSKY RIVER

LAKE ERIE

WORKSHEET 1

Source	Position	Point of Entry	Area km^2	Surface features		Diagram
				Soils	Other	
Loss Creek	1	A	230			 Rural LAKE ERIE Urban F E D C B A T = 1.0 T = 1.0 T = 1.0 T = 1.0 T = 1.0 13 11 10 12 8 9 7 6 4 3 5 1 2
Bucyrus City	2	A	8.5			
Broken Sword	3	B	217			
Upper Sandusky River	4	B	325			
Upper Sandusky City	5	B	6.7			
Tymochtee Cr	6	C	593			
Middle Sandusky	7	C	640			
Honey Creek	8	D	386			
Tiffin City	9	D	17.4			
Wolf Cr	10	E	385			
Rock Cr	11	E	464			
Fremont City	12	E	13.7			
Lower Sandusky	13	F	730			

incremental level of treatment which can only be implemented subsequent to the previous stage of control. In other words, for any given loading source, implementation of Stage II control implies that Stage I control is also implemented. A more detailed discussion of the control alternatives considered in this example is given below.

POINT SOURCE AND URBAN RUNOFF LOADS (WORKSHEET 2)

The purpose of this worksheet is to compile loading information for all of the significant urban pollutant sources, including point sources, stormwater runoff, combined sewer overflows, and other sources such as construction runoff and runoff from unsewered areas. On this and all subsequent worksheets, reference is made to column letters and worksheet numbers. For example, b_2 refers to column "b" on worksheet "2".

Point Sources

Municipal: Within the Sandusky River Basin, four municipal point sources were found to contribute the majority of the total phosphorus point source load. The municipalities served by these point sources are Bucyrus, Upper Sandusky, Tiffin and Fremont. For each of these plants data were obtained on population served, flow from the treatment plant, and the total phosphorus concentration in the effluent. Several small point sources also exist, but since the cumulative load from these plants is very small, they are not considered in this example.

Various levels of phosphorus control presently exist at the four Sandusky plants. However, for example purposes it will be assumed that no phosphorus control has been implemented at these plants. This will allow for a comparison of several control options among plants. Initial phosphorus concentrations in the discharge water is thus assumed to be 4 mg/L P. This value, representative of many treatment plants without phosphorus control (Drynan, 1978; Sonzogni et al., 1978), is entered in column b_2 for all four plants. The average daily flow from each of the municipalities is given in column a_2 (million gallons per day). The average annual total phosphorus load in kg/yr (column c_2) is calculated by multiplying flow (mgd) by concentration (mg/L) and then multiplying this product by a conversion factor (columns $a_2 \times b_2 \times 1{,}382 = c_2$).

The next step is to enter on Worksheet 2 data which describe the impact of selected remedial programs on total phosphorus loads from municipal point sources. Two stages of phosphorus control at each of the four municipal wastewater treatment facilities included in this case study are examined:

Stage I Control:	chemical precipitation to reduce the total phosphorus effluent concentration to 1.0 mg/L.
Stage II Control:	additional treatment to further reduce the total phosphorus effluent concentration from 1.0 mg/L to 0.5 mg/L.

POINT AND URBAN RUNOFF LOADS

TOTAL P LOADS

WORKSHEET 2

	Column →	a_2	b_2	c_2	d_2	e_2	f_2	g_2	h_2	i_2	j_2	k_2	l_2
		Point			Storm			Combined			Unsewered *		
Source	Position	Flow mgd	Conc. mg/L	Load kg/yr	Area km^2	UAL $kg/km^2/yr$	Load kg/yr	Area km^2	UAL $kg/km^2/yr$	Load kg/yr	Area km^2	UAL $kg/km^2/yr$	Load kg/yr
INITIAL CONDITION													
Bucyrus City	2	2.5	4.0	13.800	1.3	250	320	7.2	900	6,500	0	-	
Upper Sandusky City	5	1.5	4.0	8,300	0	-		6.7	250	1,700	0	-	
Tiffin City	9	3.2	4.0	17,700	7.0	250	1,800	10.4	1,000	10,400	0	-	
Fremont	12	5.1	4.0	28,200	1.4	250	350	12.3	1,000	12,300	0	-	
TOTAL				68.000	9.7		2,500	36.6		30,900			
STAGE I													
Bucyrus City	2	2.5	1.0	3,400	1.3	188	240	7.2	846	6,091			
Upper Sandusky City	5	1.5	1.0	2,100	-	-	-	6.7	235	1,574			
Tiffin City	9	3.2	1.0	4,400	7.0	188	1,300	10.4	940	9,776			
Fremont	12	5.1	1.0	7,000	1.4	188	260	12.3	940	11,562			
TOTAL				16,900			1,800			29,003			
STAGE II													
Bucyrus City	2	2.5	0.5	1,728	1.3	140	182	7.2	630	4,536			
Upper Sandusky City	5	1.5	0.5	1,036			-	6.7	175	1,172			
Tiffin City	9	3.2	0.5	2,211	7.0	140	980	10.4	700	7,280			
Fremont City	12	5.1	0.5	3,524	1.4	140	196	12.3	700	8,610			
TOTAL				8,499			1,358			21,598			

$c_2 = a_2 \times b_2 \times 1,382$ → where 1,382 is the conversion factor (mg/L x mgd x 1,382) = kg/yr.

$f_2 = d_2 \times e_2$

$i_2 = g_2 \times h_2$

$l_2 = j_2 \times k_2$

* Can include construction sites or septic tank areas.

UAL→Unit Area Load

These new effluent concentrations are entered in column b_2 and used to calculate a Stage I and Stage II controlled municipal load (column c_2). The cost of implementing these programs is presented later (Worksheet 6).

Industrial: No industries were identified as discharging significant levels of phosphorus to the Sandusky River. If industries were present, they would be entered on Worksheet 2 as point sources. Control measures may or may not be proposed and evaluated.

Stormwater Runoff

For the Sandusky little data were available on the urban area served by different types of sewer systems (separate, combined or unsewered). As a result, only approximate values are given in Worksheet 2 for the area served by all the sewer systems.

The estimated area served by stormwater sewers for each of the four cities included in this analysis are presented in column d_2 (the City of Upper Sandusky is served by combined sewers only and thus has an entry of "0" in column d_2). These values are then multiplied by a total phosphorus unit area load (UAL) (from the companion paper by Sonzogni et al., 1980) representative of stormwater sewer areas, and the products are entered as an initial condition in column f_2. The UAL applied here -- 250 kg/km^2/yr -- reflects medium industrial activity within the urban area. The initial condition values entered in column f_2 represent runoff loadings assuming no remedial measures are in effect.

The next step is to calculate the reduced loads that result from a Stage I and Stage II program for controlling stormwater runoff. In this example the following separate stormwater sewer control programs are examined:

Stage I Control:	streetsweeping at 7-day intervals with vacuum sweepers.
Stage II Control:	Stage I control plus detention and sedimentation of stormwater runoff.

These and other programs are discussed in the companion paper by Sonzogni et al. (1980).

Implementing the Stage I program is assumed to result in a 25 percent reduction in the uncontrolled diffuse loading from all separate sewered areas. Implementation of Stage II programs will realize another 20 percent total phosphorus load reduction from the initial stormwater load. These reductions are illustrated in the Stage I and Stage II UALs and total loads contained in columns e_2 and f_2, respectively.

Combined Sewer Overflows

Estimates of diffuse loadings from urban areas served by combined sewers are obtained in a manner similar to that used for separate stormwater sewers. The UALs for the initial loading condition presented in column h_2 are taken from the companion paper and reflect combined sewer overflows typical of cities in the Great Lakes region.

The following combined sewer overflow control programs are examined:

Stage I Control: streetsweeping at 7-day intervals with vacuum sweepers.

Stage II Control: Stage I control plus detention and treatment of the combined sewer overflow.

The Stage I program results in about a 5 percent reduction in total phosphorus load, and Stage II will result in an additional 25 percent reduction in the total phosphorus loading (Johnson et al., 1978). The Initial, Stage I, and Stage II UALs are presented in column i_2. These values reflect medium industrial activity within the combined sewer area.

If other pollutant sources, such as septic tanks and feedlots (see the companion paper by Sonzogni et al., 1980) were to be considered, they would be included in Worksheet 2. These sources would be treated as point sources. In many cases, loads would be calculated separately for these sources and entered directly onto column c_2.

RURAL NON-CROPLAND AREAS (WORKSHEET 3)

The purpose of Worksheet 3 is to calculate loads for rural land uses within each sub-basin that will not be treated for phosphorus reductions. For the Sandusky River Basin, two main land uses of this type were identified: grassland and woodlands. If measured loads are available, they would be used directly. In the Sandusky, loads had to be estimated using the appropriate UALs (as given in the companion paper).

The area of each non-cropland land use (columns a_3, d_3 and g_3) is multiplied by the appropriate unit area load (columns b_3, e_3 and h_3) to provide an estimate of the annual diffuse total phosphorus load. The results are presented in columns c_3, f_3 and i_3. These values are subsequently summed in column j_3 to produce a total rural non-cropland load for each sub-basin. This load represents a part of the total phosphorus budget but will not be considered for treatment measures.

RURAL CROPLAND AREAS - (WORKSHEET 4)

The primary tool used to estimate pollutant loadings and the effect of control measures in cropland areas is the Universal Soil Loss Equation (USLE). The components and the application of this equation are discussed in detail in the companion paper and in Wischmeier and

RURAL NON-CROPLAND AREAS

TOTAL P LOADS

WORKSHEET 3

Source	Column › Position	a_3 Grass Area * km^2	b_3 Grass UAL kg/km^2/yr	c_3 Grass Load kg/yr	d_3 Woodland Area * km^2	e_3 Woodland UAL kg/km^2/yr	f_3 Woodland Load kg/yr	g_3 Other ** Area km^2	h_3 Other ** UAL kg/km^2/yr	i_3 Other ** Load kg/yr	j_3 Total Non-Cropland Load kg/yr
Loss Creek	1	11.83	10	118	25.04	10	250				368
Broken Sword	3	3.59	10	36	18.17	10	180				216
Upper Sandusky River	4	12.81	10	128	34.38	10	344				472
Tymochtee	6	9.04	25	226	47.13	10	471				697
Middle Sandusky	7	17.27	10	173	67.96	10	680				853
Honey Creek	8	3.17	10	31	44.07	10	441				472
Wolf Creek	10	7.57	10	76	22.89	10	229				305
Rock Creek	11	12.14	10	121	56.47	10	565				686
Lower Sandusky (Soil 1)	13	10.00	25	250	74.54	10	745				1,077
Lower Sandusky (Soil 2)	13	8.25	10	82	–	10		274.88 Water, Wetlands			
TOTAL		95.67		1,241	390.65		3,905				5,146

$c_3 = a_3 \times b_3$
$f_3 = d_3 \times e_3$
$i_3 = g_3 \times h_3$
$j_3 = c_3 + f_3 + i_3$

* Weighted Extrapolation
** Includes septic tank failures
UAL = Unit Area Load

RURAL CROPLAND AREAS

UNIVERSAL SOIL LOSS EQUATION/TOTAL PHOSPHORUS LOAD ESTIMATES

WORKSHEET 4

Column *		a_4						b_4	c_4	d_4	e_4	f_4	g_4
			Universal Soil Loss Equations Coefficients					Soil Loss (T/ac/yr) A	Soil Loss (mt/ha/yr) A	Total Gross Erosion (mt/yr)	Pol-lutant Delivery Ratio	Pollutant Reduction Efficiency	Total P (mt/yr) Y
Source	Position	Cropland Area (ha)	Rainfall & Runoff R	Soil Erodibility K	Topo-graphic LS	Cover & Management C	Support Practice P						
INITIAL													
Loss Cr	1	18,984	125	.35	.402	.233	1	4.1	9.3	176,551			18.4
Broken Sword	3	18,719	125	.38	.424	.233	1	4.7	10.5	196,544			20.5
Upper Sandusky	4	27,460	130	.42	.426	.245	1	5.7	12.7	348,742			36.6
Tymochtee	6	52,840	138	.32	.357	.260	1	4.1	9.2	486,128			51.0
Middle Sandusky	7	54,236	138	.38	.381	.260	1	5.2	11.6	629,138			66.0
Honey Cr	8	34,355	125	.35	.338	.237	1	3.5	7.8	267,964			28.0
Wolf Cr	10	34,311	125	.29	.256	.237	1	2.2	5.0	171,555			18.0
Rock Cr	11	40,990	125	.34	.427	.237	1	4.3	9.6	393,504			41.2
Lower Sandusky (Soil 1)	13	24,355	125	.32	.410	.268	1	4.4	9.9	241,114			25.2
Lower Sandusky (Soil 2)	13	10,000	125	.28	.434	.237	1	3.6	8.1	81,000			8.5
TOTAL		316,250						4.2	9.5	2,992,250	.000105	NA	313.4
STAGE I													
Loss Cr	1					.108		1.9	4.3	81,269		1.0	8.5
Broken Sword	3					.099		2.0	4.5	84,756		1.0	8.9
Upper Sandusky	4					.103		2.4	5.3	146,494		1.0	15.4
Tymochtee	6					.108		1.7	3.8	203,721		1.0	21.4
Middle Sandusky	7					.110		2.2	4.9	265,887		1.0	27.9
Honey Cr	8					.101		1.5	3.4	117,017		1.0	12.3
Wolf Cr	10					.108		1.0	2.2	75,938		1.0	8.0
Rock Cr	11					.105		1.9	4.2	171,635		1.0	18.0
Lower Sandusky (Soil 1)	13					.116		1.9	4.2	102,601		1.0	10.8
Lower Sandusky (Soil 2)	13					.099		1.5	3.4	34,468		1.0	3.6
TOTAL								1.8	4.0	1,283,786	.000105	1.0	134.8
STAGE II													
Loss Cr	1					.034		0.6	1.4	27,196		1.0	2.8
Broken Sword	3					.035		0.7	1.5	27,692		1.0	2.9
Upper Sandusky	4					.034		0.8	1.7	47,388		1.0	5.0
Tymochtee	6					.032		0.5	1.2	65,143		1.0	6.8
Middle Sandusky	7					.035		0.7	1.6	86,613		1.0	9.1
Honey Cr	8					.034		0.5	1.1	38,678		1.0	4.1
Wolf Cr	10					.032		0.3	0.7	25,309		1.0	2.6
Rock Cr	11					.033		0.6	1.4	56,460		1.0	5.9
Lower Sandusky (Soil 1)	13					.036		0.6	1.4	33,572		1.0	3.5
Lower Sandusky (Soil 2)	13					.033		0.5	1.1	11,278		1.0	1.2
TOTAL								0.6	1.3	419,329	.000105	1.0	44.0

b_4 = RKLSCP

c_4 = b_4 x 2.243

d_4 = c_4 x a_4

e_4 · Pollutant delivery ratio - The ratio of pollutant to total gross erosion for Initial Case.

f_4 · Pollutant reduction efficiency - The extent that a pollutant yield is decreased from a given decrease in potential gross erosion.

NA · Not Applicable.

Smith (1978). In this example, and in most WATERSHED applications, the USLE will be applied to large areas. Thus, the USLE coefficients represent averages over relatively large cropland areas. If large-scale averaging is not appropriate for a particular area (i.e., crop types differ significantly within portions of a sub-basin), it is possible to further divide the sub-basin. In this example, the lower Sandusky sub-basin, position No. 13, is broken into "Soil 1" and "Soil 2" areas because of a differance in the K, LS and C factors. The "Soil 1" area is composed of clay surface material while "Soil 2" is made up of loam surface material.

Ideally, the water quality manager derives unique values for the USLE variables which reflect the characteristics of the local study area. If this cannot be done, some generalized values may be obtained from the literature (e.g., Wischmeier and Smith, 1978).

Most of the USLE values in this example were derived from the U.S. Army Corps of Engineers' Lake Erie Wastewater Management Study (LEWMS) on the Sandusky basin (Baker, 1980; U.S. Army Corps, 1979b; Urban *et al.*, 1978). Because these data do not exactly fit the sub-basin boundaries, some modifications were necessary.

Changes in the "C" factor reflect changes in the cover type and crop rotation resulting from control program implementation. The "P" factor is 1.0 for this example, which implies that very little contour or strip-cropping is used in this basin.

The USLE is applied to each sub-basin to generate a potential gross erosion rate for sediment (in tons/acre) presented in column b_4. This value is then converted to mt/ha in column c_4. Values in c_4 are then multiplied by the area (a_4) to yield the total potential gross erosion of sediment in mt/yr (d_4). These erosion rates are then summed for the entire cropland area, yielding a total load of 2,992,250 mt/yr (as shown in d_4).

In this example, a total river basin cropland load is calculated by subtracting the urban loads and rural non-cropland loads from the monitored river mouth load. The urban loads consist of the summation of columns c_2, f_2 and i_2; while the rural non-cropland loads are found in column j_3. In this example, 101,400 kg/yr of total phosphorus are coming from urban land (before treatment) and another 5,146 kg/yr of total phosphorus are coming from rural non-cropland. Subtracting these amounts from the monitored river mouth load of 420,000 kg/yr gives a rural cropland total phosphorus load of 313,454 kg/yr from the entire river basin. Note that these loads are average annual loads and not indicative of any one year.

The cropland total phosphorus load (313.4 mt/yr or 313,454 kg/yr) and the cumulative potential gross erosion (2,992,250 mt/yr) are used to estimate the total phosphorus delivery ratio for the entire river basin. This is accomplished by dividing the total phosphorus load by the total gross erosion. In this case, a pollutant delivery ratio of 0.000105 was obtained for total phosphorus. This value, entered in column e_4, is multiplied by all of the potential gross erosion values in column d_4 to obtain cropland total phosphorus loads from each of the sub-basins. These are listed in column g_4. A more detailed discussion of the rationale for calculating the phosphorus load in this way is given in the companion paper.

The next step is to determine what effect the Stage I and Stage II control programs have on reducing soil loss and the associated total phosphorus load. Stage I and Stage II control of total phosphorus loadings attributable to cropland runoff are defined as follows:

Stage I Control:	technical assistance to educate farmers on the techniques and economic advantages of adopting conservation tillage practices.
Stage II Control:	Stage I control plus application of more intensive conservation tillage practices (i.e., no-till where soils will support it).

Both of these programs include crop rotation. A new cover factor ("C") is then calculated for each of these programs. The Stage I and Stage II "C" values were derived from the Corps' study (Urban *et al.*, 1978). "C" values (and thus "A" values) decrease under the new tillage practices because of increased cover on the cropland (see Worksheet 4).

The phosphorus load reduction caused by a remedial measure may not necessarily be equivalent to the reduction in gross erosion. To account for this fact, Worksheet 4 includes column f_4, "Pollution Reduction Efficiency", where the estimated percent reduction in total phosphorus relative to gross erosion reduction can be entered. This column only applies to the load reduction analysis.

In this example, the pollutant reduction efficiency has been set at 1.0 (column f_4). This is done only to simplify the illustration, since the pollution reduction efficiency is likely to be less than 1.0 for the cropland strategies chosen (U.S. Army Corps of Engineers, 1979a).

If the pollution reduction efficiency were to be considered. the Stage I load (L_I) would be calculated from the following equation:

$$L_I = L_{initial} - [(E_{initial} - E_I) \times PRE \times PDR]$$

where:

	Worksheet Column
L_I = Stage I Total Phosphorus Load (mt/yr),	g_4
$L_{initial}$ = Initial Total Phosphorus Load (mt/yr),	g_4
$E_{initial}$ = Initial Gross Erosion (mt/yr),	d_4
E_I = Stage I Gross Erosion (mt/yr),	d_4
PRE = Pollutant Reduction Efficiency (unitless), and	e_4
PDR = Pollutant Delivery Ratio (unitless)	f_4

For example, if the Pollutant Reduction Efficiency for Loss Creek in Worksheet 4 was 0.8 for the Stage I phosphorus load reduction program, L_I would be calculated as follows:

$$L_I = 18.4 - [(176{,}551 - 81{,}269) \times 0.8 \times 0.000105] = 10.4 \text{ mt/yr}$$

By considering pollutant reduction efficiency to be 0.8 as opposed to 1.0, the Stage I load for Loss Creek is increased from 8.5 to 10.4 mt/yr.

LOADING SUMMARY - (WORKSHEET 5)

This sheet is used to summarize information on pollutant loadings to the river channel with and without control programs in effect. Column a_5 contains the initial "uncontrolled" total phosphorus load from each of the 21 major sources identified in the Sandusky River Basin example. Columns b_5 and c_5 contain the adjusted total phosphorus loads with Stage I and Stage II control in effect, respectively. All values in these first three columns are obtained from Worksheets 2, 3, and 4. Columns d_5 and e_5 reflect the load reductions achieved through the two stages of control.

Point Sources

It is assumed that municipal wastewater treatment plants are discharging at a 4.0 mg/L total phosphorus effluent concentration without phosphorus control programs in place (column a_5). Under this condition, the four major treatment facilities included in this example -- Bucyrus, Upper Sandusky, Tiffin and Fremont -- account for a total phosphorus load to the river channel of 68,000 kg/yr, approximately 15 percent of the total for all sources.

Under a Stage I control program at these municipal point sources (total phosphorus effluent concentration = 1.0 mg/L), the load would be reduced to 17,000 kg/yr -- a decrease of 75 percent. Subsequent implementation of phosphorus controls to reach a 0.5 mg/L total phosphorus effluent concentration would reduce the municipal point source load to 8,500 kg/yr.

Urban Runoff

Assuming no programs in effect to control urban runoff in the four urban areas identified here, the total phosphorus load entering the river channel from this source (stormwater and combined sewer overflow) is estimated at 41,870 kg/yr (about 10 percent of the total load from all sources). Approximately 75 percent of the load -- 30,900 kg/yr -- is associated with combined sewer areas.

Inspection of Worksheet 5 shows that a Stage I control program (streetsweeping at 7-day intervals) would reduce the urban runoff contribution by 2,567 kg/yr. Stage II control (streetsweeping plus detention/treatment of stormwater runoff and combined sewer overflows) would reduce the load by another 7,847 kg/yr.

LOADING SUMMARY

TOTAL P

WORKSHEET 5

Column →		a_5	b_5	c_5	d_5	e_5
		Initial Load to River Channel (kg/yr)	Load to River Channel With Controls in Place (kg/yr)		Load Reductions (kg/yr)	
Source	Position		Stage I	Stage II	Stage I	Stage II
Loss Creek	1	18,868	8,868	3,168	10,000	5,700
Bucyrus - municipal	2	13,800	3,400	1,728	10,400	1,672
- storm	2	320	240	182	80	58
- combined	2	6,500	6,091	4,536	409	1,555
Broken Sword	3	20,816	9,116	3,116	11,700	6,000
Upper Sandusky River	4	37,072	15,872	7,272	21,200	8,600
Upper Sandusky - municipal	5	8,300	2,100	1,036	6,200	1,064
- storm	5	0	--	--	--	--
- combined	5	1,700	1,574	1,172	126	402
Tymochtee Creek	6	51,697	22,097	7,497	29,600	14,600
Middle Sandusky	7	66,853	28,753	9,953	38,100	18,800
Honey Creek	8	28,572	12,772	4,572	15,800	8,200
Tiffin - municipal	9	17,700	4,400	2,211	13,300	2,189
- storm	9	1,800	1,300	980	500	320
- combined	9	10,400	9,776	7,280	624	2,496
Wolf Creek	10	18,305	8,305	2,905	10,000	5,400
Rock Creek	11	41,986	18,686	6,586	23,300	12,100
Fremont - municipal	12	28,200	7,000	3,524	21,200	3,476
- storm	12	350	260	196	90	64
- combined	12	12,300	11,562	8,610	738	2,952
Lower Sandusky	13	34,877	15,477	5,777	19,400	9,700
TOTAL		420,416	187,649	82,301	232,767	105,348

a_5 → Initial: municipal (c_2), storm (f_2), combined sewer (i_2), rural ($j_3 + g_4$).

b_5 → Stage I: municipal (c_2), storm (f_2), combined sewer (i_2), rural ($j_3 + g_4$).

c_5 → Stage II: municipal (c_2), storm (f_2), combined sewer (i_2), rural ($j_3 + g_4$).

$d_5 = a_5 - b_5$ → The loading reduction from the initial condition when Stage I is implemented.

$e_5 = b_5 - c_5$ → The loading reduction from the Stage I condition when Stage II is implemented.

Rural Runoff

Rural runoff represents the major source of total phosphorus loads to the Sandusky River. Nearly 75 percent of the initial total phosphorus load to the Sandusky River (column a_5) is attributable to rural runoff within the nine sub-basins. Of the 319,000 kg/yr entering the river channel from this source, approximately 98 percent or 313,400 kg/yr (column g_4) is derived from cropland areas. As discussed earlier, in this example only cropland areas are considered for remedial action. Therefore, the diffuse load from non-cropland -- 5,146 kg/yr -- is not affected by implementation of Stage I and Stage II control programs.

Worksheet 5 shows that a Stage I rural runoff control program will reduce the total phosphorus load to the Sandusky River channel by 179,100 kg/yr. This is more than three times the load reduction achieved through Stage I control of both urban runoff and point sources. The Stage II program results in an additional total phosphorus load reduction of 89,100 kg/yr -- over 5 times the reduction from Stage II control of urban runoff and point sources.

In considering the total load reductions which are achieved through the control programs included in this case study, Worksheet 5 indicates that Stage I control at all major sources within the Sandusky River Basin would result in a 232,767 kg/yr reduction in the total phosphorus load to the river channel (column d_5 total). This represents a more than 50 percent decrease in the initial load (column a_5 total). Thus, the total phosphorus input to the Sandusky River under Stage I control at all sources is 187,649 kg/yr (column b_5 total).

If Stage II programs were in effect at all major sources, an additional load reduction of 105,348 kg/yr (column e_5 total) could be achieved. This would yield a total phosphorus load of 82,301 kg/yr to the river channel (column d_5 total).

PROGRAM COSTS (WORKSHEET 6)

Worksheet 6 is used to compute the costs of implementing remedial measures to control pollutant loads from each source. In this case study, costs are estimated for Stage I and Stage II programs to reduce total phosphorus loadings from each of the 21 major sources listed on Worksheet 6.

Cropland Costs

By summing the rural land area in column a_6 (Worksheet 6), a total of 3,163.6 km^2 is obtained. This corresponds to the total area of cropland contained within the Sandusky River Basin that will be considered for Stage I and Stage II control.

The estimated cost of implementing a Stage I rural program contained in column b_6 -- providing technical assistance to encourage mulch-till or chisel plowing in cropland areas -- is \$65/km^2/yr (see the companion paper, Sonzogni et al., 1980, for a discussion of how

PROGRAM COSTS

TOTAL P REDUCTIONS

WORKSHEET 6

	Column →	a_6	b_6	c_6	d_6	e_6	f_6	g_6	h_6
			Nonpoint			Point		Total Cost of Program	
Source	Position	Area Treated (km^2)	Initial to Stage I ($/km^2/yr)	Stage I to Stage II ($/km^2/yr)	Units Served	Initial to Stage I ($/cap/yr)	Stage I to Stage II ($/cap/yr)	Initial to Stage I ($/yr)	Stage I to Stage II ($/yr)
Loss Creek	1	189.8	65	3,000	--	--	--	12,337	569,400
Bucyrus - municipal	2	--	--	--	13,500	2.4	3.6	32,400	48,600
- storm	2	1.3	7,400	8,600	--	--	--	9,620	11,180
- combined	2	7.2	7,400	24,700	--	--	--	53,280	177,840
Broken Sword Creek	3	187.2	65	3,000	--	--	--	12,168	561,600
Upper Sandusky River	4	274.6	65	3,000	--	--	--	17,849	823,800
Upper Sandusky - municipal	5	--	--	--	6,250	2.4	3.6	15,000	22,500
- storm	5	0	--	--	--	--	--	--	--
- combined	5	6.7	7,400	24,700	--	--	--	49,580	165,490
Tymochtee Creek	6	528.4	65	3,000	--	--	--	34,346	1,585,200
Middle Sandusky	7	542.4	65	3,000	--	--	--	35,256	1,627,200
Honey Creek	8	343.6	65	3,000	--	--	--	22,334	1,030,800
Tiffin - municipal	9	--	--	--	26,000	2.4	3.6	62,400	93,600
- storm	9	7.0	7,400	8,600	--	--	--	51,800	60,200
- combined	9	10.4	7,400	24,700	--	--	--	76,960	256,880
Wolf Creek	10	343.1	65	3,000	--	--	--	22,302	1,029,300
Rock Creek	11	409.9	65	3,000	--	--	--	26,644	1,229,700
Fremont - municipal	12	--	--	--	19,730	2.4	3.6	47,352	71,028
- storm	12	1.4	7,400	8,600	--	--	--	10,360	12,040
- combined	12	12.3	7,400	24,700	--	--	--	91,020	303,810
Lower Sandusky	13	343.6	65	3,000	--	--	--	22,334	1,030,800
TOTAL								705,342	10,710,902

a_6 = a_4 cropland, or d_2 or g_2 or j_2 urban land.

b_6 = Unit area cost of going from the initial cropland condition to a Stage I cropland program.

c_6 = Unit area cost of going from the Stage I cropland program to Stage II.

d_6 = Units served (i.e., population served for municipal plants).

e_6 = Unit cost of going from the initial point source load to a Stage I load.

f_6 = Unit cost of going from the Stage I point source program to Stage II.

g_6 = $a_6 \times b_6$, or $d_6 \times e_6$.

h_6 = $a_6 \times c_6$, or $d_6 \times f_6$.

this value was derived). Multiplying this value by the land to be treated in each sub-basin in column a_6 yields a total annual cost for Stage I control.

The estimated cost of adding a further level of rural control (Stage II -- more intensive tillage practices) is another $3,000/km^2/yr (column c_6). Again, applying this figure to the area subject to treatment results in the incremental annual cost for Stage II control of cropland runoff (column $a_6 \times c_6 = h_6$). Thus, if a Stage II program were implemented on cropland in a sub-basin within the Sandusky River Basin, the annual cost would be the sum of columns g_6 and h_6 for cropland sub-basins.

Cost of Urban Runoff Control

In this case study, the cost of urban runoff control can vary with both the stage of treatment and the type of sewer system present. As shown in column b_6, the annual cost per unit area treated through a Stage I program is the same for all urban land ($7,400). This is consistent with the assumption that the Stage I program (streetsweeping at 7-day intervals) is applied in both separate and combined sewer areas.

If a Stage I program is implemented on all urban land identified in this example, the resulting total annual cost for control in separate and combined sewer areas (column g_6) is obtained by multiplying each urban area contained in column a_6 by the annual unit area cost of Stage I control in column b_6.

The annual unit area cost of Stage II urban runoff control is significantly higher for combined sewer areas than for separate sewer areas. Column c_6 shows a unit cost of $8,600/km^2/yr for separate sewer areas and $24,700/km^2/yr for combined sewer areas. This difference is due to the fact that Stage II control in the combined sewer areas includes treatment of combined sewer overflows. The incremental cost for Stage II control of these urban runoff sources (column h_6) is obtained by multiplying column $a_6 \times c_6$. A total Stage II cost is calculated by adding the values in column g_6 to those in h_6.

Costs of Point Source Control

The cost of a Stage I program to control phosphorus loads from each point source (column g_6) is obtained by multiplying the population served at each facility (column d_6) by the annual cost per capita (column e_6). Stage I control at the four treatment plants considered in this example would cost $2.4/capita/year (Sonzogni *et al.*, 1980). This represents the cost of treatment to achieve a 1.0 mg/L total phosphorus effluent concentration (Stage I).

The incremental cost of Stage II control at all treatment plants (column h_6) is obtained by multiplying the population served in column d_6 by the incremental unit cost increase in column f_6 ($3.6/cap/yr). As noted above, a Stage II program is defined as treatment to achieve a 0.5 mg/L total phosphorus effluent concentration.

COST-EFFECTIVENESS ANNALYSIS (WORKSHEET 7 -- MASTER)

The purpose of Worksheet 7, the master worksheet, is to consolidate the loading and cost information with downstream transmission data so that a cost-effective analysis can be performed. The previous worksheets have been designed to help the manager make reasonable decisions about each portion of the drainage area. Worksheet 7 draws all those decisions together so that the cost-effectiveness of control programs can be compared and ranked on a common basis.

As discussed earlier, the value entered in column a_7 represents the portion of a pollutant that is transmitted from the point of entry in the main channel to the receiving water (river mouth). In this example it is assumed that all pollutants that enter the main channel of the Sandusky River eventually reach the mouth (Verhoff et al., 1978; Baker, 1980). Thus, a "T" of 1.0 is assumed throughout the main channel. Transmission coefficients of less than 1.0 at any point along the channel will have a direct effect on the cost-effectiveness calculations. This effect will be discussed in a following section on WATERSHED modifications.

Column b_7 provides an opportunity for analyzing the biologically available or dissolved form of a parameter. In the case of phosphorus, it may be very important to know the effect that a program will have on the biologically available fraction, as discussed in the companion paper. Using this column, various assumptions can be made in regard to the portion of the total phosphorus that is biologically available. For example, municipal wastewater sources could be assumed 100 percent available, while cropland or rural runoff could be set at 50 percent (column b_7 value of 0.5). Again, to keep this example simple, only the total form is examined here. Thus column b_7 is not applicable (NA).

Column c_7 represents the total load to the main channel (surface water). This value is taken directly from Worksheet 5, column a_5.

Column d_7 represents the calculated load at the river mouth. To perform this calculation, any losses that occur (or fractions that are not biologically available if this were applicable) along the channel must be considered. The load at the mouth is given as the product of columns a_7, b_7, and c_7. For example, the effective transmission at position 1 is 1.0 (column a_7). In this case, column b_7 does not apply (because only the total phosphorus content is considered). The value of the total load (column c_7) entering the river channel is 18,868 kg/yr. Multiplying a_7 by c_7 yields a river mouth load of 18,868 kg/yr. In this example, column d_7 always equals column c_7 because the effective transmission equals 1.0. By summing all values in d_7 (420,416 kg/yr), a total river mouth load is computed.

Load reductions and costs of the programs are used to compute the cost-effectiveness of the various control programs. If transmission losses occur (or if biological availability is being studied), the load reduction must be adjusted to reflect a load reduction at the river mouth (the point at which the control programs will be evaluated). Columns d_5 and e_5 (Worksheet 5) represent the load reductions likely to

COST-EFFECTIVENESS ANALYSIS

TOTAL P

WORKSHEET 7 -- MASTER

Column →		a_7	b_7	c_7	d_7	e_7	f_7	g_7	h_7
Source	Position	Effective Transmission	Bio-Available Fraction	Total Load to Surface Water (kg/yr)	Load at Mouth (kg/yr)	Load Reduction at Mouth (kg/yr)	Cost of Program ($/yr)	Cost Per Unit Removed at Mouth ($/kg)	Cost-Effective Rank
STAGE I						STAGE I	STAGE I	STAGE I	
Loss Creek	1	1	NA	18,868	18,868	10,000	12,337	1.2	7
Bucyrus - municipal	2	1		13,800	13,800	10,400	32,400	3.1	12
- storm	2	1		320	320	80	9,620	120.2	27
- combined	2	1		6,500	6,500	409	53,280	130.3	33
Broken Sword	3	1		20,816	20,816	11,700	12,168	1.0	3
Upper Sandusky River	4	1		37,072	37,072	21,200	17,849	0.8	1
Upper Sandusky - municipal	5	1		8,300	8,300	6,200	15,000	2.4	11
- storm	5	1		--	--	--	--	--	--
- combined	5	1		1,700	1,700	126	49,580	393.5	34
Tymochtee Creek	6	1		51,697	51,697	29,600	34,346	1.2	5
Middle Sandusky	7	1		66,853	66,853	38,100	35,256	0.9	2
Honey Creek	8	1		28,572	28,572	15,800	22,334	1.4	8
Tiffin - municipal	9	1		17,700	17,700	13,300	62,400	4.7	13
- storm	9	1		1,800	1,800	500	51,800	103.6	23
- combined	9	1		10,400	10,400	624	76,960	123.3	30
Wolf Creek	10	1		18,305	18,305	10,000	22,302	2.2	10
Rock Creek	11	1		41,986	41,986	23,300	26,644	1.1	4
Fremont - municipal	12	1		28,200	28,200	21,200	47,352	2.2	9
- storm	12	1		350	350	90	10,360	115.1	26
- combined	12	1		12,300	12,300	738	91,020	123.3	28
Lower Sandusky	13	1		34,877	34,877	19,400	22,334	1.2	6
TOTAL				420,416	420,416		705,342		
					**Subtotal	232,767 **			

a_7 → Effective Transmission from Source to River Mouth (usually 1.0).

b_7 → Portion of parameter that is judged to be biologically available.

$c_7 = a_5$

$d_7 = a_7 \times b_7 \times c_7$ → Load at the mouth with losses and availability factored in.

$e_7 = d_5 \times a_7 \times b_7$ (Stage I), or $= e_5 \times a_7 \times b_7$ (Stage II).

$f_7 = g_6$ (Stage I), or h_6 (Stage II).

$g_7 = f_7 \div e_7$

h_7 → The rank from smallest to largest value in g_7 (cost-effectiveness): NOTE - A Stage II program must follow a Stage I in the same position.

COST-EFFECTIVENESS ANALYSIS

TOTAL P

WORKSHEET 7 -- MASTER (cont'd.)

Column →		a_7	b_7	c_7	d_7	e_7	f_7	g_7	h_7
Source	Position	Effective Transmission	Bio-Available Fraction	Total Load to Surface Water (kg/yr)	Load at Mouth (kg/yr)	Load Reduction at Mouth (kg/yr)	Cost of Program ($/yr)	Cost Per Unit Removed at Mouth ($/kg)	Cost-Effective Rank
STAGE II						STAGE II	STAGE II	STAGE II	
Loss Creek	1					5,700	569,400	99.9	21
Bucyrus - municipal	2					1,672	48,600	29.1	16
- storm	2					58	11,180	192.7	38
- combined	2					1,555	177,840	114.4	34
Broken Sword	3					6,000	561,600	93.6	19
Upper Sandusky River	4					8,600	823,800	95.8	20
Upper Sandusky - municipal	5					1,064	22,500	21.1	15
- storm	5					--	--	--	--
- combined	5					402	165,490	411.7	40
Tymochtee Creek	6					14,600	1,585,200	108.6	25
Middle Sandusky	7					18,800	1,627,200	86.6	18
Honey Creek	8					8,200	1,030,800	125.7	32
Tiffin - municipal	9					2,189	93,600	42.8	17
- storm	9					320	60,200	188.1	35
- combined	9					2,496	256,880	102.9	31
Wolf Creek	10					5,400	1,029,300	190.6	37
Rock Creek	11					12,100	1,229,700	101.6	22
Fremont - municipal	12					3,476	71,028	20.4	14
- storm	12					64	12,040	188.1	36
- combined	12					2,952	303,810	102.9	29
Lower Sandusky	13					9,700	1,030,800	106.3	24
					**Subtotal	105,348 **	10,710,902		
				PHASE I	Subtotal	232,767			
				PHASE II	Subtotal	105,348			
					TOTAL	338,115			

a_7 → Effective Transmission from Source to River Mouth (usually 1.0).

b_7 → Portion of parameter that is judged to be biologically available.

c_7 = a_5

d_7 = $a_7 \times b_7 \times c_7$ → Load at the mouth with losses and availability factored in.

e_7 = $d_5 \times a_7 \times b_7$ (Stage I), or = $e_5 \times a_7 \times b_7$ (Stage II).

f_7 = g_6 (Stage I), or h_6 (Stage II).

g_7 = $f_7 \div e_7$

h_7 → The rank from smallest to largest value in g_7 (cost-effectiveness): NOTE - A Stage II program must follow a Stage I in the same position.

occur at the point of entry if Stage I and then Stage II programs are implemented. These reductions are adjusted to represent reductions at the receiving water (river mouth) by multiplying d_5 x a_7 x b_7 for Stage I, and e_5 x a_7 x b_7 for Stage II. The results are entered in column e_7. Again, because no transmission losses occur in this example (T = 1.0 in column a_7), the values in column e_7 for Stage I control equal those in column d_5, while values in column e_7 for Stage II control equal those in column e_5.

The costs of the control programs, computed on Worksheet 6, are entered in column f_7. These are the incremental costs of going from the initial load to a Stage I load (column g_6) and then to a Stage II load (column h_6).

Column g_7 represents the cost per unit of pollutant removed at the receiving water (river mouth). These values are calculated for each stage of implementation by dividing column f_7 by column e_7. In other words, the total cost of the control stage is divided by the total reduction achieved at the river mouth. This allows all stages of remedial effort to be compared on the basis of their effectiveness of total phosphorus load reductions at the receiving water.

The final step on Worksheet 7 is to rank the programs by cost-effectiveness values. In instances where programs have the same cost-effectiveness value, the maximum load reduction at the receiving water is checked (column e_7) and the program that removes the most phosphorus at the mouth is ranked first (the total cost of the program could also be the secondary consideration).

Column h_7 contains the cost-effectiveness ranking. The #1 (most cost-effective) program is the one that has the smallest cost-effectiveness value. As shown on Worksheet7, the #1 program in this example is Cropland Stage I--providing technical assistance for converting from conventional tillage practices to minimum or chisel-plow tillage--in the Upper Sandusky sub-basin (position 4, Stage I). The annual cost of this program would be \$0.8/kg of phosphorus removed at the receiving water (column g_7). The load at the mouth would be reduced by 21,200 kg/yr (column e_7).

Note that a Stage II program in column g_7 cannot precede a Stage I program (also in column g_7) at the same position. This is because all Stage II costs and load reductions are incremental, i.e., in addition to Stage I costs and load reductions. For example, the cost-effectiveness (at the river mouth) of a Stage II program to control runoff from combined sewered areas in the City of Fremont (position 12) is \$102.9/kg. This is less than the corresponding Stage I program (\$123.3/kg). However, the Stage II combined sewer program is ranked higher (#29) than the Stage I combined sewer program (#28) because the Stage II cost-effectiveness calculations are based upon the Stage I program being funded and in place.

SUMMARY OF PROGRAMS (WORKSHEET 8)

All of the programs are arranged in their ranked order on Worksheet 8. Worksheet 8 also contains the load reductions (column a_8) for each program. A summation of the load reductions is given in column b_8. In this example, selecting programs ranked 1 through 10 would reduce the total phosphorus load at the mouth by about 200,300 kg/yr. Moving down the list in column a_8, fairly significant load reductions can be achieved through programs 25. Program 26, it will be noted, reduces the river mouth load by only 90 kg/yr.

Columns c_8 and d_8 present the costs for each program and a summation of costs. The values in column c_8 are obtained from column e_7. Column d_8 contains a running summation of column c_8. Selecting programs 1-17 would accomplish a 240,000 kg/yr (column b_8) reduction at a cost of $600,000/yr (column d_8).

It is interesting to note that selection of one more program (#18) would reduce the river mouth load another 18,800 kg/yr. However, the additional cost ($1.6 million) is almost three times the total cost for the first 17 programs. This implies that, after program 17, costs per unit reduction begin to rise quite sharply.

Using column b_8 and column d_8, a manager can quickly estimate an approximate cost for any level of load reduction, or determine a reasonable load reduction for any level of funding within a drainage area. For example, a 300,000 kg/yr reduction (if items 1-24 are in place) would cost about $6.5 million per year to operate. On the other hand, if $9 million per year were available to control pollution, the first 31 programs could be implemented and about a 320,000 kg/yr reduction in the total phosphrous load could be achieved.

Many trade-offs can be made by managers in deciding which programs to implement. Numerous political and sociological factors, not considered in this example, can influence decision-making. The ranking does, however, give the manager an excellent perspective on the options available in the Sandusky River Basin and provides the groundwork for further analysis.

EXAMPLE MODIFICATION #1 - Transmission Losses Occur

To provide some insight into the effect various assumptions have on the ranking process, the effect of altering several variables on Worksheet 7 has been examined. First, it will be assumed that all values in Worksheet 7 are the same as those presented in the previous Sandusky River Basin example, with the exception of the effective transmission from the Loss Creek sub-basin. Modified Worksheet 7, column a_7, indicates that an effective transmission of 0.5 should now be applied to the diffuse loading from Loss Creek.

According to the diagram presented on Worksheet 1, a shift in the effective transmission to Loss Creek would imply that the transmission coefficient between entry points A and B has also shifted. Consequently, to be consistent with the physical representation of the

SUMMARY OF PROGRAMS

TOTAL P

WORKSHEET 8

	Column →		a_8	b_8	c_8	d_8
Source	Rank (h_7)	Stage	Load Reduction (kg/yr)	Σ Load Reduction (kg/yr)	Cost of Reduction ($/yr)	Σ Reduction Costs ($/yr)
Cropland - Upper Sandusky	1	I	21,200	21,200	17,849	17,849
Cropland - Middle Sandusky	2	I	38,100	59,300	35,256	53,105
Cropland - Broken Sword	3	I	11,700	71,000	12,168	65,273
Cropland - Rock Creek	4	I	23,300	94,300	26,644	91,917
Cropland - Tymochtee	5	I	29,600	123,900	34,346	126,263
Cropland - Lower Sandusky	6	I	19,400	143,300	22,334	148,597
Cropland - Loss Creek	7	I	10,000	153,300	12,337	160,934
Cropland - Honey Creek	8	I	15,800	169,100	22,334	183,268
Municipal - Fremont	9	I	21,200	190,300	47,352	230,620
Cropland - Wolf Creek	10	I	10,000	200,300	22,302	252,922
Municipal - Upper Sandusky	11	I	6,200	206,500	15,000	267,922
Municipal - Bucyrus	12	I	10,400	216,900	32,400	300,322
Municipal - Tiffin	13	I	13,300	230,200	62,400	362,722
Municipal - Fremont	14	II	3,476	233,676	71,028	433,750
Municipal - Upper Sandusky	15	II	1,064	234,740	22,500	456,250
Municipal - Bucyrus	16	II	1,672	236,412	48,600	504,850
Municipal - Tiffin	17	II	2,189	238,601	93,600	598,450
Cropland - Middle Sandusky	18	II	18,800	257,401	1,627,200	2,225,650
Cropland - Broken Sword	19	II	6,000	263,401	561,600	2,787,250
Cropland - Upper Sandusky	20	II	8,600	272,001	823,800	3,611,050
Cropland - Loss Creek	21	II	5,700	277,701	569,400	4,180,450
Cropland - Rock Creek	22	II	12,100	289,801	1,229,700	5,410,150
Storm Sewer - Tiffin	23	I	500	290,301	51,800	5,461,950
Cropland - Lower Sandusky	24	II	9,700	300,001	1,030,000	6,491,950
Cropland - Tymochtee	25	II	14,600	314,601	1,585,200	8,077,150
Storm Sewer - Fremont	26	I	90	314,691	10,360	8,087,510
Storm Sewer - Bucyrus	27	I	80	314,771	9,620	8,097,130
Combined Sewer - Fremont	28	I	738	315,509	91,020	8,188,150
Combined Sewer - Fremont	29	II	2,952	318,461	303,810	8,491,960
Combined Sewer - Tiffin	30	I	624	319,085	76,960	8,568,920

$a_8 = e_7$
$b_8 = \Sigma\ a_8$
$c_8 = f_7 = g_6$
$d_8 = \Sigma\ c_8$

SUMMARY OF PROGRAMS

TOTAL P

WORKSHEET 8 (cont'd.)

	Column →		a_8	b_8	c_8	d_8
Source	Rank (h_7)	Stage	Load Reduction (kg/yr)	Σ Load Reduction (kg/yr)	Cost of Reduction ($/yr)	Σ Reduction Costs ($/yr)
Combined Sewer - Tiffin	31	II	2,496	321,581	256,880	8,825,800
Cropland - Honey Creek	32	II	8,200	329,781	1,030,800	9,856,600
Combined Sewer - Bucyrus	33	I	409	330,190	53,280	9,909,880
Combined Sewer - Bucyrus	34	II	1,555	331,745	177,840	10,087,720
Storm Sewer - Tiffin	35	II	320	332,065	60,200	10,147,920
Storm Sewer - Fremont	36	II	64	332,129	12,040	10,159,960
Cropland - Wolf Creek	37	II	5,400	337,529	1,029,300	11,189,260
Storm Sewer - Bucyrus	38	II	58	337,587	11,180	11,200,440
Combined Sewer - Upper Sandusky	39	I	126	337,713	49,580	11,250,020
Combined Sewer - Upper Sandusky	40	II	402	338,115	165,490	11,415,510

$a_8 = e_7$

$b_8 = \Sigma a_8$

$c_8 = f_7 = g_6$

$d_8 = \Sigma c_8$

COST-EFFECTIVENESS ANALYSIS

TOTAL P

MODIFICATION #1

WORKSHEET 7 -- MASTER

Column →		a_7	b_7	c_7	d_7	e_7	f_7	g_7	h_7
Source	Position	Effective Transmission	Bio-Available Fraction	Total Load to Surface Water (kg/yr)	Load at Mouth (kg/yr)	Load Reduction at Mouth (kg/yr)	Cost of Program ($/yr)	Cost Per Unit Removed at Mouth ($/kg)	Cost-Effective Rank
STAGE I						STAGE I	STAGE I	STAGE I	
Loss Creek	1	1 0.5	NA	18,868	9,434 ~~18,868~~	~~10,000~~ 5,000	12,337	~~1.2~~ 2.4	~~7~~ 12
Bucyrus - municipal	2	1		13,800	13,800	10,400	32,400	3.1	12
- storm	2	1		320	320	80	9,620	120.2	27
- combined	2	1		6,500	6,500	409	53,280	130.3	33
Broken Sword	3	1		20,816	20,816	11,700	12,168	1.0	3
Upper Sandusky River	4	1		37,072	37,072	21,200	17,849	0.8	1
Upper Sandusky - municipal	5	1		8,300	8,300	6,200	15,000	2.4	11
- storm	5	1		--	--	--	--	--	--
- combined	5	1		1,700	1,700	126	49,580	393.5	34
Tymochtee Creek	6	1		51,697	51,697	29,600	34,346	1.2	5
Middle Sandusky	7	1		66,853	66,853	38,100	35,236	0.9	2
Honey Creek	8	1		28,572	28,572	15,800	22,334	1.4	8
Tiffin - municipal	9	1		17,700	17,700	13,300	62,400	4.7	13
- storm	9	1		1,800	1,800	500	51,800	103.6	23
- combined	9	1		10,400	10,400	624	76,960	123.3	30
Wolf Creek	10	1		18,305	18,305	10,000	22,302	2.2	10
Rock Creek	11	1		41,986	41,986	23,300	26,644	1.1	4
Fremont - municipal	12	1		28,200	28,200	21,200	47,352	2.2	9
- storm	12	1		350	350	90	10,360	115.1	26
- combined	12	1		12,300	12,300	738	91,020	123.3	28
Lower Sandusky	13	1		34,877	34,877	19,400	22,334	1.2	6
TOTAL				420,416	~~420,416~~ 410,982 **Subtotal	227,767 ~~232,767~~ **	705,342		

a_7 → Effective Transmission from Source to River Mouth (usually 1.0).

b_7 → Portion of parameter that is judged to be biologically available.

c_7 = a_5

d_7 = $a_7 \times b_7 \times c_7$ → Load at the mouth with losses and availability factored in.

e_7 = $d_5 \times a_7 \times b_7$ (Stage I), or = $e_5 \times a_7 \times b_7$ (Stage II).

f_7 = g_6 (Stage I), or h_6 (Stage II).

g_7 = $f_7 \div e_7$

h_7 → The rank from smallest to largest value in g_7 (cost-effectiveness): NOTE - A Stage II program must follow a Stage I in the same position.

COST-EFFECTIVENESS ANALYSIS

TOTAL P

MODIFICATION #1 (cont'd.)

WORKSHEET 7 -- MASTER (cont'd.)

	Column →	a_7	b_7	c_7	d_7	e_7	f_7	g_7	h_7
Source	Position	Effective Transmission	Bio-Available Fraction	Total Load to Surface Water (kg/yr)	Load at Mouth (kg/yr)	Load Reduction at Mouth (kg/yr)	Cost of Program ($/yr)	Cost Per Unit Removed at Mouth ($/kg)	Cost-Effective Rank
STAGE II						STAGE II	STAGE II	STAGE II	
Loss Creek	1					~~5,700~~ 2,850	569,400	~~99.9~~ 199.8	~~21~~ 39
Bucyrus - municipal	2					1,672	48,600	29.1	16
- storm	2					58	11,180	192.7	38
- combined	2					1,555	177,840	114.4	34
Broken Sword	3					6,000	561,600	93.6	19
Upper Sandusky River	4					8,600	823,800	95.8	20
Upper Sandusky - municipal	5					1,064	22,500	21.1	15
- storm	5					--	--	--	--
- combined	5					402	165,490	411.7	40
Tymochtee Creek	6					14,600	1,585,200	108.6	25
Middle Sandusky	7					18,800	1,627,200	86.6	18
Honey Creek	8					8,200	1,030,800	125.7	32
Tiffin - municipal	9					2,189	93,600	42.8	17
- storm	9					320	60,200	188.1	35
- combined	9					2,496	256,880	102.9	31
Wolf Creek	10					5,400	1,029,300	190.6	37
Rock Creek	11					12,100	1,229,700	101.6	22
Fremont - municipal	12					3,476	71,028	20.4	14
- storm	12					64	12,040	188.1	36
- combined	12					7,952	303,810	102.9	29
Lower Sandusky	13					9,700	1,030,800	106.3	24
					**Subtotal	102,498 ~~105,348~~ **	10,710,902		
				PHASE I	Subtotal	~~232,767~~ →	227,767		
				PHASE II	Subtotal	~~105,348~~ →	102,498		
					TOTAL	~~338,115~~ →	330,265		

a_7 → Effective Transmission from Source to River Mouth (usually 1.0).

b_7 → Portion of parameter that is judged to be biologically available.

$c_7 = a_5$

$d_7 = a_7 \times b_7 \times c_7$ → Load at the mouth with losses and availability factored in.

$e_7 = d_5 \times a_7 \times b_7$ (Stage I), or $= e_5 \times a_7 \times b_7$ (Stage II).

$f_7 = g_6$ (Stage I), or h_6 (Stage II).

$g_7 = f_7 \div e_7$

h_7 # The rank from smallest to largest value in g_7 (cost-effectiveness): NOTE - A Stage II program must follow a Stage I in the same position.

Sandusky River Basin adopted in this case study, the total phosphorus loading from Bucyrus City (position 2) would also be affected by this modification. However, to simplify the anlaysis, this example only considers the impact of a change in the effective transmission for one pollutant source (Loss Creek).

As shown on modified Worksheet 7, the total phosphorus load at the river mouth attributable to Loss Creek would decrease to approximately 9,400 kg/yr as a result of the aforementioned change in effective transmission (column $d_7 = a_7 \times b_7 \times c_7$). This implies that control of cropland runoff in Loss Creek would not be as effective in reducing the load at the river mouth. For example, Stage I control in Loss Creek would now reduce the river mouth load by only 5,000 kg/yr (column $e_7 = a_7 \times b_7 \times d_5$). The Stage I cost-effectiveness in column g_7 then changes from $1.2/kg/yr to $2.4/kg/yr (column $g_7 = e_7 \times f_7$). This adjusted cost-effectiveness value changes the rank of Stage I control in Loss Creek from 7 to 12 (column h_7).

The change in effective transmission for Loss Creek becomes even more significant when evaluating the Stage II program. As can be seen in column e_7, the load reduction attributable to Stage II control now changes from 5,700 Kg/yr to 2,850 Kg/yr. Therefore, the cost-effectiveness of the program changes from $99.9/Kg to $199.8/Kg (column e_7). Based on this new cost-effectiveness value, Stage II control in Loss Creek is ranked #38 (column h_7).

EXAMPLE MODIFICATION #2 - Changes in Costs

In this modification it is assumed that the annual costs of the streetsweeping programs within the separate and combined sewer areas of Tiffin, Ohio (Stage I control) have been raised to $76,800 and $108,139, respectively. The effect of this change is shown on Modification #2, Worksheet 7. The cost-effectiveness of Stage I control within the separate sewered area of Tiffin changes from $103.6/kg to $153.6/kg, while Stage I control in the combined sewer area has an adjusted cost-effectiveness value of $173.3/kg (column g_7). As a result, the cost-effectiveness ranking would change from 23 to 35 for the stormwater program, and from 30 to 36 for the combined sewer overflow program (column h_7). This also has an effect on the Stage II rankings. Because the Stage II programs follow Stage I, the rank of the Stage II stormwater program would change from 35 to 38 and the combined sewer overflow program from 31 to 37.

SUMMARY OF EXAMPLE AND MODIFICATIONS

As is true in most all modeling applications, the accuracy of the results obtained from WATERSHED are dependent on the accuracy of the input data base. Small changes in transmission coefficients, cost assumptions or loading reduction values can have marked impacts on program evaluations. However, WATERSHED can provide a reasonable first-cut evaluation of programs using a variety of data bases.

COST-EFFECTIVENESS ANALYSIS

TOTAL P

MODIFICATION #2

WORKSHEET 7 -- MASTER

	Column →	a_7	b_7	c_7	d_7	e_7	f_7	g_7	h_7
Source	Position	Effective Transmission	Bio-Available Fraction	Total Load to Surface Water (kg/yr)	Load at Mouth (kg/yr)	Load Reduction at Mouth (kg/yr)	Cost of Program ($/yr)	Cost Per Unit Removed at Mouth ($/kg)	Cost-Effective Rank
STAGE I						STAGE I	STAGE I	STAGE I	
Loss Creek	1	1	NA	18,868	18,868	10,000	12,337	1.2	7
Bucyrus - municipal	2	1		13,800	13,800	10,400	32,400	3.1	12
- storm	2	1		320	320	80	9,620	120.2	27
- combined	2	1		6,500	6,500	409	53,280	130.3	33
Broken Sword	3	1		20,816	20,816	11,700	12,168	1.0	3
Upper Sandusky River	4	1		37,072	37,072	21,200	17,849	0.8	1
Upper Sandusky - municipal	5	1		8,300	8,300	6,200	15,000	2.4	11
- storm	5	1		--	--	--	--	--	--
- combined	5	1		1,700	1,700	126	49,580	393.5	34
Tymochtee Creek	6	1		51,697	51,697	29,600	34,346	1.2	5
Middle Sandusky	7	1		66,853	66,853	38,100	35,256	0.9	2
Honey Creek	8	1		28,572	28,572	15,800	22,334	1.4	8
Tiffin - municipal	9	1		17,700	17,700	13,300	62,400	4.7	13
- storm	9	1		1,800	1,800	500	51,800	~~103.6~~ 163.6	~~23~~ 35
- combined	9	1		10,400	10,400	624	76,960	~~123.3~~ 173.3	~~30~~ 36
Wolf Creek	10	1		18,305	18,305	10,000	22,302	2.2	10
Rock Creek	11	1		41,986	41,986	23,300	26,644	1.1	4
Fremont - municipal	12	1		28,200	28,200	21,200	47,352	2.2	9
- storm	12	1		350	350	90	10,360	115.1	26
- combined	12	1		12,300	12,300	738	91,020	123.3	28
Lower Sandusky	13	1		34,877	34,877	19,400	22,334	1.2	6
TOTAL				420,416	420,416		705,342		
					**Subtotal	232,767 **			

a_7 → Effective Transmission from Source to River Mouth (usually 1.0).

b_7 → Portion of parameter that is judged to be biologically available.

$c_7 = a_5$

$d_7 = a_7 \times b_7 \times c_7$ → Load at the mouth with losses and availability factored in.

$e_7 = d_5 \times a_7 \times b_7$ (Stage I), or $= e_5 \times a_7 \times h_7$ (Stage II).

$f_7 = g_6$ (Stage I), or h_6 (Stage II).

$g_7 = f_7 \div e_7$

h_7 → The rank from smallest to largest value in g_7 (cost-effectiveness): NOTE - A Stage II program must follow a Stage I in the same position.

COST-EFFECTIVENESS ANALYSIS

TOTAL P

MODIFICATION #2 (cont'd.)

WORKSHEET 7 -- MASTER (cont'd.)

	Column →	a_7	b_7	c_7	d_7	e_7	f_7	g_7	h_7
Source	Position	Effective Transmission	Bio-Available Fraction	Total Load to Surface Water (kg/yr)	Load at Mouth (kg/yr)	Load Reduction at Mouth (kg/yr)	Cost of Program ($/yr)	Cost Per Unit Removed at Mouth ($/kg)	Cost-Effective Rank
STAGE II						STAGE II	STAGE II	STAGE II	
Loss Creek	1					5,700	569,400	99.9	21
Bucyrus - municipal	2					1,672	48,600	29.1	16
- storm	2					58	11,180	192.7	38
- combined	2					1,555	177,840	114.4	34
Broken Sword	3					6,000	561,600	93.6	19
Upper Sandusky River	4					8,600	823,800	95.8	20
Upper Sandusky - municipal	5					1,064	22,500	21.1	15
- storm	5					--	--	--	--
- combined	5					402	165,490	411.7	40
Tymochtee Creek	6					14,600	1,585,200	108.6	25
Middle Sandusky	7					18,800	1,627,200	86.6	18
Honey Creek	8					8,200	1,030,800	125.7	32
Tiffin - municipal	9					2,189	93,600	42.8	17
- storm	9					320	60,200	188.1	~~35~~ 38
- combined	9					2,496	256,980	102.9	~~31~~ 37
Wolf Creek	10					5,400	1,029,300	190.6	37
Rock Creek	11					12,100	1,229,700	101.6	22
Fremont - municipal	12					3,476	71,028	20.4	14
- storm	12					64	12,040	188.1	36
- combined	12					2,952	303,810	102.9	29
Lower Sandusky	13					9,700	1,030,800	106.3	24
					**Subtotal	105,348 **	10,710,902		
				PHASE I	Subtotal	232,767			
				PHASE II	Subtotal	105,348			
					TOTAL	338,115			

a_7 → Effective Transmission from Source to River Mouth (usually 1.0).

b_7 → Portion of parameter that is judged to be biologically available.

$c_7 = a_5$

$d_7 = a_7 \times b_7 \times c_7$ → Load at the mouth with losses and availability factored in.

$e_7 = d_5 \times a_7 \times b_7$ (Stage I), or $= e_5 \times a_7 \times b_7$ (Stage II).

$f_7 = g_6$ (Stage I), or h_6 (Stage II).

$g_7 = f_7 \div e_7$

h_7 → The rank from smallest to largest value in g_7 (cost-effectiveness): NOTE - A Stage II program must follow a Stage I in the same position.

There is a great deal of flexibility built into this approach so that managers may custom-fit WATERSHED to any drainage area. It is usually desirable to execute WATERSHED several times using different assumptions or ranges in costs and load reductions associated with different programs. The value of such a sensitivity anlaysis was demonstrated in the Sandusky River example, where different results were obtained under new assumptions involving transmission and costs.

The worksheets can be used to extract more information than highlighted in this case study. For example, cost information on Worksheet 6 can be used to compare the total control costs for each major category (cropland, urban runoff, and point sources). Stage I programs over the entire basin would cost \$200,000/yr for cropland, \$340,000/yr for urban land and \$160,000/yr for point sources (from column g_6). The Stage II programs would cost the amount for Stage I control plus another \$9,500,000/yr for cropland, \$990,000/yr for urban land and \$240,000/yr for point sources. This is typical of the type of data that does not directly assist the WATERSHED process but can help the managers analyze their plans. This type of information is available from all worksheets.

Natural variability in the behavior of most river systems makes it difficult to precisely predict pollutant loads and the effect of control programs for any single year. However, by compiling an input information base which best reflects conditions in or typical of the river basin under study, WATERSHED provides a logical, orderly way to organize and use river basin data for the purpose of making pollution control management decisions.

REFERENCES CITED

Baker, D.B. (1980). Personal Communication. Data on the Sandusky River.

Drynan, W.R. (1978). Relative Costs of Achieving Various Levels of Phosphorus Control at Municipal Wastewater Treatment Plants in the Great Lakes Basin," International Joint Commission, Great Lakes Regional Office, Windsor, Ontario.

Honey Creek Joint Board of Supervisors (1980). "Honey Creek Watershed Project Tillage Demonstration Results 1979," U.S. Army Corps of Engineers, Buffalo District, Buffalo, New York.

International Joint Commission (1978). "Environmental Management Strategy for the Great Lakes System (PLUARG)," Great Lakes Regional Office, Windsor, Ontario.

Johnson, M.G., Comeau, J.L., Heidtke, T.M., and W.C. Sonzogni (1978). "Management Information Base and Overview Modeling," International Joint Commission, Great Lakes Regional Office, Windsor, Ontario.

Sonzogni, W.C., Monteith, T.J., Bach, W.N., and V.G. Hughes (1978). "United States Great Lakes Tributary Loadings," Great Lakes Basin Commission for the International Joint Commission, Great Lakes Regional Office, Windsor, Ontario.

Sonzogni, W.C., Monteith, T.J., Heidtke, T.M., and R.A.C. Sullivan (1980). "WATERSHED - A Management Technique for Choosing Among Point and Nonpoint Control Strategies. Part 1 - Teory and Process Framework," Great Lakes Basin Commission, Ann Arbor, Michigan.

Urban, D.R., Logan, T.J., and J.R. Adams (1978). "Application of the Universal Soil Loss Equation in the Lake Erie Drainage Basin," U.S. Army Corps of Engineers, Buffalo District, Buffalo, New York.

U.S. Army Corps of Engineers (1975). "Preliminary Feasibility Report, Volume III, Appendix B, Lake Erie Wastewater Management Study," Buffalo District, Buffalo, New York.

U.S. Army Corps of Engineers (1979a). "Lake Erie Wastewater Management Study Methodology Report," Buffalo District, Buffalo, New York.

U.S. Army Corps of Engineers (1979b). "Land Management Alternatives in the Lake Erie Drainage Basin," Buffalo District, Buffalo, New York.

U.S. Environmental Protection Agency (1979). "Costs and Water Quality Impacts of Reducing Agricultural Nonpoint Source Pollution," Office of Research and Development, Athens, Georgia.

Verhoff, F.H., Melfi, D.A., Yaksich, S.M., and D.B. Baker (1978). "Phosphorus Transport in Rivers," U.S. Army Corps of Engineers, Buffalo District, Buffalo, New York.

Wischmeier, W.H., and D.D. Smith (1978). "Predicting Rainfall Erosion Losses," USDA, Agricultural Handbook No. 537, Science and Education Administration, Washington, D.C.

BMP CAUSE AND EFFECT RELATIONSHIPS BY SIMULATION

by

L.F. Huggins, D.B. Beasley and E.J. Monke[1]

We are currently entering a period in which many questions are being raised about the effectiveness and the cost efficiency of our national efforts to improve the quality of our water resources. These are valid concerns and they cannot be easily answered. The questions are especially difficult when they deal with non-point source (NPS) pollution. Much of this difficulty stems from fact that it is very hard to quantify sources of such pollution and to determine cause-effect relationships between sources and possible treatment methodologies.

Before presenting a technique to evaluate certain classes of agricultural Best Management Practices (BMPs), some general remarks about the problem of identifying cause-effect relations for NPS pollution are in order.

BASIC APPROACHES

Two fundamentally different approaches to establishing cause-effect relationships between NPS pollution and possible control measures are field monitoring studies and simulation techniques which rely on models. The relative strengths and weaknesses of these two methodologies are quite different. Obviously, when both approaches are used concurrently the strengths of each tend to overcome the other's weaknesses.

Cause-Effect or Correlation?

Two or more variables are statistically correlated when the numerical value or level of one, the independent variable(s), infers a likely value for the other, the dependent variable. Two variables are related by cause-effect when there are governing physical laws which require that a change in level of the independent variable directly causes a prescribed change in the dependent variable. Variables which are related by cause-effect considerations will certainly show a high degree of correlation. However, statistical correlation does not, of itself, permit one to infer that a cause-effect relationship exists between the correlated variables.

Statistical correlation will occur because variables are related by physical cause-effect considerations or because both variables are influenced by another unconsidered variable(s). To illustrate the latter situation, consider the statistical correlation shown in Figure 1. Assume a need exists to predict the level of consumption of alcohol

---

1. Respectively, Professor, Assistant Professor and Professor, Dept. of Agricultural Engineering, Purdue University, W. Lafayette, IN.

and the only readily available data pertains to average professorial salaries (to make the illustration more personal, substitute your own profession as the label for the independent variable, since the correlation can be expected to change very little). Such a correlation is quite valid and useful for this purpose.

Now consider the situation if this correlation is deemed to be a cause-effect relationship and a national decision is made to reduce total alcohol consumption. It would then follow that the appropriate course of action would be to reduce professorial salaries to attain this goal. Such action would rightly be considered ludicrous, especially if it is your profession's salary that is used as the independent correlation variable.

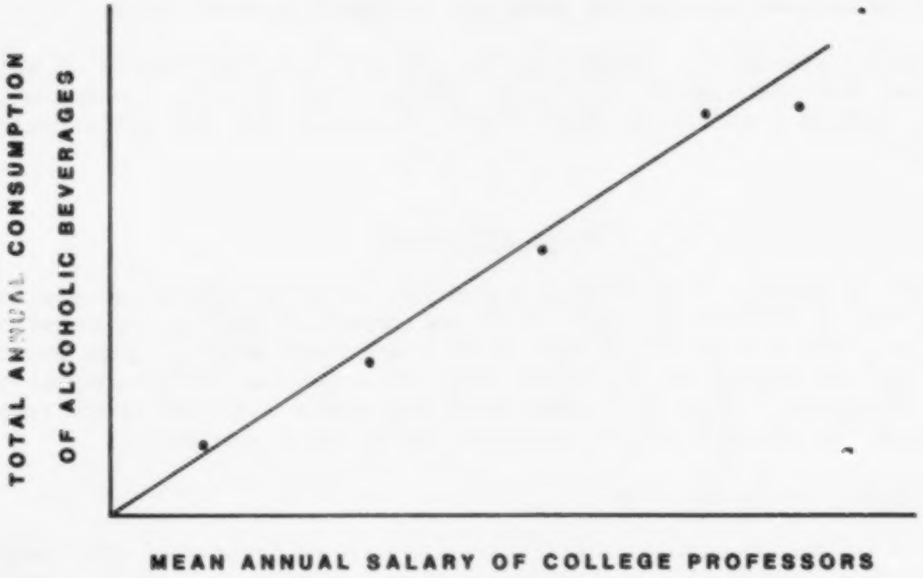


Figure 1. Statistical correlation example.

The main point to be made from this example is that it is much easier to compute statistical correlations for variables which are influenced by many factors than to establish true cause-effect relationships. A very real hazard exists that these correlations will be interpreted as demonstrating cause-effect, especially when there is justification for assuming at least part of the correlation effect is due to the physical interaction between variables.

Monitoring

Monitoring, as it relates to water pollution programs, is the collection of field data on and about a watershed under study. The overwhelming majority, conservatively estimated in excess of 95 percent, of the scientific and informed lay communities believe the only way to accurately assess impacts of a water quality improvement program is with a well-designed and well-executed monitoring program. Unfortunately, this is a false hope as it applies to NPS pollution, particularly on a watershed scale. While it is certainly possible to precisely determine the chemical constituents in a water sample, it is another matter to evaluate the true significance of these constituents and their origin.

A well-designed, comprehensive non-point monitoring program is very costly and time consuming. Except for irrigated agriculture, non-point water pollution is generated by rainfall and the resulting runoff. Many years of record are required to remove confounding influences due to the many combinations of rainfall intensities and antecedent conditions which occur.

If scale-up problems of translating plot-scale studies to a real watersheds are to be avoided, it is necessary to monitor what occurs on natural, but non-uniform and only partially controlled, watersheds. However, lack of complete experimental control results in reduced sensitivity to treatments and statistical confounding.

Finally, monitored watershed data are strictly applicable only to the area being monitored. We do attempt to transfer results to other "similar" areas, but all too often results are unwisely used under very dissimilar physiographic and climatic conditions. This occurs because reliable non-point source pollution data are quite scarce.

For all these reasons, one must conclude that it is not economically feasible to implement NPS monitoring programs which will yield general relationships about benefits from individual BMPs installed at various locations within a watershed. In fact, the monitoring situation would be quite dismal were it not for modeling.

Monitoring and modeling are inseparably linked. Concurrent modeling provides a means of transforming single practice measurements into watershed scale projections. Unique storm patterns during a relatively short monitoring interval can be transformed into more nearly average patterns. On the other hand, concurrent monitoring on a continuous and comprehensive basis for relatively long time periods is absolutely vital if modeling authenticity is to be improved. Such storm related monitoring is needed for watersheds in different geographic regions. Monitored data are the very foundation of model evaluation and development, but they are in dismally short supply.

Simulation

Simulation is an analysis methodology which uses a mathematical model, usually implemented in the form of a computer program, to predict the behavior of a system. The mathematical model is a collection of equations which are purported to represent the phyical laws governing the system's behavior.

Simulation studies allow cause-effect questions to be asked about potential pollution control measures because both naturally occurring and hypothetical situations can be analyzed. Results are available very quickly and inexpensively. The single, most important disadvantage with models developed to simulate non-point pollution is that, to varying degrees, they are all inaccurate.

Inaccurate results are often obtained from models which attempt to simulate non-point pollution because of the many complex factors and interactions involved. To build a practical model, a developer is required to to use relationships which only approximate the true governing physical laws. Approximations are necessary for two reasons: (1) inadequate knowledge about controlling physical processes and their interactions and (2) a desire to reduce data preparation and computer time costs.

Model Selection

Choosing a model with which to simulate non-point pollution is not simple. Numerous models exist. This is a direct consequence of the complexity of the problem and the varying degrees of accuracy which are thought necessary for different applications. No currently available model is capable of even crudely approximating the vast range of conditions and physical processes that fall under the broad heading of NPS pollution.

The "best" model is entirely dependent upon which subset from the comprehensive list of non-point pollution problems is most appropriate for a given situation. Primary factors to consider in selecting a model are: (1) availability and cost (both for data preparation and computer time), (2) applicability to pollutants of primary interest, and (3) the accuracy and sensitivity with which proposed treatment measures are simulated.

Despite shortcomings of models currently available for simulating non-point source pollution, simulation is the only viable means for rational planning and evaluation of cost effective non-point pollution control programs. Furthermore, while it complicates the user's selection process, much effort is currently underway to improve the more promising models.

There are two primary impediments to more rapid progress toward improving NPS models. First, there is a severe lack of reliable, continuous monitored data from test watersheds and little evidence of the public patience required for such studies to be of value. Secondly, model predictions are considered 'theoretical' and completely unreliable. This latter attitude has resulted from early experiences with very crude models or current efforts which utilize models that are grossly inappropriate for a particular application.

CASE STUDIES

One particular simulation model designed for application to non-irrigated, row-crop agriculture is called ANSWERS (Areal, Non-point Source Watershed Environment Response Simulation) (1). ANSWERS was developed at Purdue University under the sponsorship of the Environmental Protection Agency, coordinated by the Allen County Soil and Water Conservation District (Black Creek Project) and the Indiana Heartland Coordinating Commission (Model Implementation Project), and in close cooperation with the Agricultural Research section of the Science and Education Administration, the Soil Conservation Service and the Agricultural Stabilization and Conservation Service. It simulates the production and transport of water, sediment, nutrients and certain chemicals from moderate-sized watersheds (current experience ranges to 15,000 ha).

Each individual watershed represents a unique combination of topography, soils, land use and management. The amount and spatial distribution of these resources strongly influence the generation of non-point pollutants. ANSWERS is a "distributed parameter" model, which means that it directly simulates impacts of the spatial distribution of each resource. In addition to predicting storm flow rates and chemical concentrations at a watershed's outlet, the model also simulates what occurs at every point within a watershed. This is accomplished by subdividing the watershed into a grid of small (.5 - 2 ha) uniform "elements" whose behavior is then individually integrated together by the model.

Planning Example

As an example of using ANSWERS as a tool for planning BMP systems, let us consider an actual situation, the Marie Delarme watershed located in NE Indiana. This watershed is composed of almost 500 ha of predominately (60 percent) poorly drained Blount, Crosby and Hoytville silty clay loams, with the remainder being moderately permeable Haskins and Rensselaer silt loams. Element slopes ranging from 1 to 6 percent and with an average of 1.9 percent. Because of the moderate relief, an element size of 2.6 ha (.1 mi. sq.) was chosen as adequate for modeling purposes. The resulting watershed representation is shown in Figure 2.

In order to rank the effectiveness of alternative control strategies, some frame of reference or "baseline condition" was required. To remove effects of particular land use and management practices from the baseline condition, all tillable land (in this case, the entire watershed) was assumed to be planted to conventionally tilled corn.

In addition to choosing a land use pattern, a time frame must also be selected. Average annual conditions are usually used. Since ANSWERS is an event-based model, simulations are performed on a storm-by-storm basis. While it is certainly possible to simulate all the storms of a "typical" year and then sum the results, this is not necessary in most situations. Many research results have shown that most of the sediment and associated chemicals are produced by the largest one or two storms for the year. Monitored data from the Black Creek watershed in NE

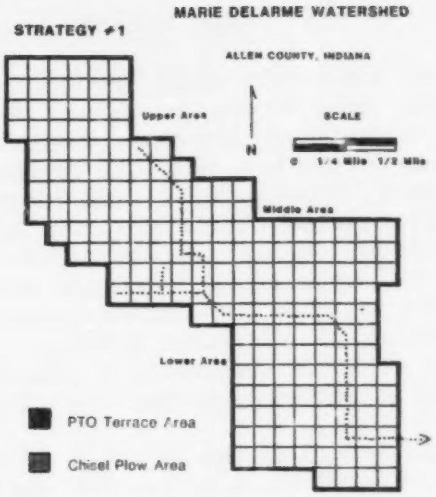


Figure 2. Elemental watershed representation.

Indiana also indicate that average annual yields can be approximated, for that region, by simulating a single 1.5 hr duration, B-distribution storm which has a recurrence interval of 8 years. This hypothetical storm was assumed to occur approximately one month after planting with antecedent soil moisture at field capacity. Simulating these conditions will approximate average annual yields for sediment and nutrients except for soluble nitrogen. Because this single storm yields only 10 percent of the expected annual water yield, annual soluble nitrogen yields was not accurately predicted by the single storm simplification.

Having decided upon a set of baseline conditions, the next step was to simulate the response of the Marie Delarme watershed to those conditions. The result of that effort is shown in Figure 3. It shows the distribution of net sediment transported from each element for the baseline condition. Note that the values, ranging from a loss in excess of 5000 kg/ha to deposition of more than 1000 kg/ha, represent net transport from each 2.6 ha element. Local erosion rates would generally be much higher that the rates of transported sediment. These net transport rates are predicted by ANSWERS without resorting to a delivery ratio concept which is very difficult to quantify. Instead, the specified watershed topography, land use and surface runoff rates determined transport capacity within the watershed.

Figure 3 gives information important for devising alternative control strategies. It shows that the highest sediment and associated nutrient yields occur in the upper third of the watershed and gradually decrease toward the outlet. While anyone knowledgeable about soil erosion and familiar with the watershed could have predicted this general trend without a simulation analysis, a distributed type model is required to quantify actual yields in the manner shown. More importantly, as the following results demonstrate, such a model can predict relative impacts of alternative control strategies.

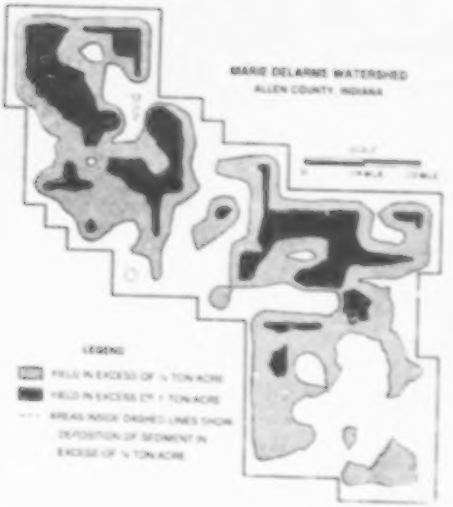
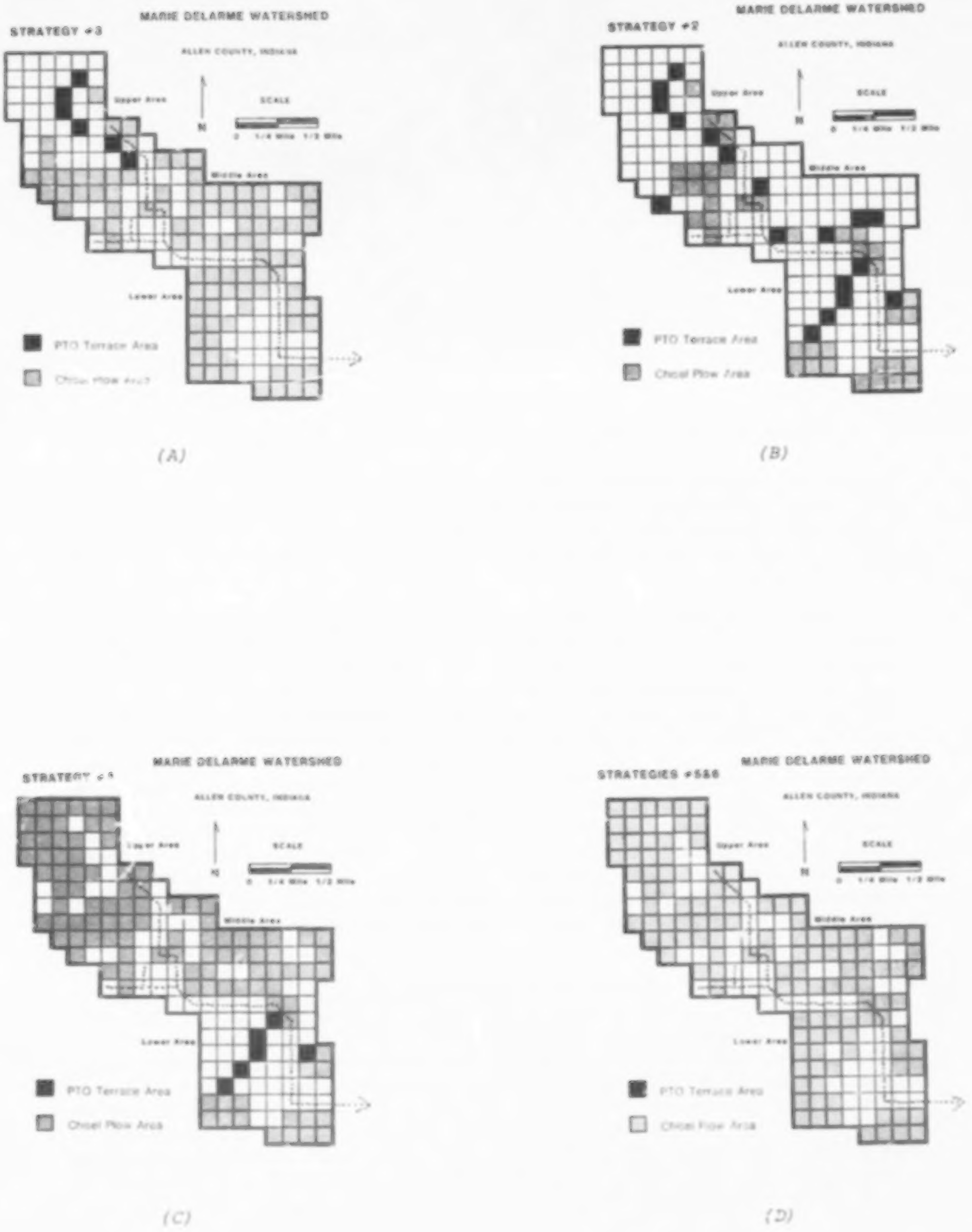

MARIE DELARME WATERSHED
ALLEN COUNTY, INDIANA
SCALE
0
1 MILE
2 MILE
LEGEND
YIELD IN EXCESS OF ½ TON/ACRE
YIELD IN EXCESS OF 1 TON/ACRE
AREAS INSIDE DASHED LINES SHOW DEPOSITION OF SEDIMENT IN EXCESS OF ½ TON/ACRE

Figure 3. Net sediment yield distribution for baseline conditions.

Figures 4a through 4d depict four alternative control strategies. While many other strategies, possibly even more effective than those chosen, could have been selected, they illustrate the scope of information made available and the manner in which simulation can be used as an effective planning tool.

Table 1 summarizes simulation results from all strategies considered. It illustrates the complicated nature of ranking alternative programs for NPS pollution control. The position of a particular strategy is very dependent upon the ranking criteria used. For example, Strategies 2-5 have been listed in terms of decreasing effectiveness for reducing sediment yield at the outlet of the watershed. However, the ranking would be quite different if annual unit cost of achieving a sediment yield reduction is employed. Still different results would be obtained if nutrient yields or concentration levels in the stream are chosen. All of these water quality improvement criteria and others are valid for developing a control program. Generally, several of them would be given some consideration. It is the ability of a comprehensive simulation model to provide information on such a wide range of factors that makes it such an attractive and even essential tool for planning NPS pollution control.

The ranking of strategies is also influenced by the choice of baseline conditions, as illustrated in Table 1 by Strategy 6. The only difference between results for Strategies 5 and 6 is the severity of the hypothetical storm used to simulate the baseline condition. For Strategy 6, a storm with 25 percent lower intensities and total volume was used. This gave a sediment yield of 640 kg/ha for the same land use as in Strategy 1. When simulation results from Strategy 5 are compared to that baseline instead of Strategy 1, they show lower absolute reductions (110 kg/ha vs. 170 kg/ha), but an increased percentage reduction. The unit cost of reducing sediment yield was also higher when the less


MARIE DELARME WATERSHED
STRATEGY #3
ALLEN COUNTY, INDIANA
Upper Area
N
SCALE
0 1/4 Mile 1/2 Mile
Middle Area
Lower Area
PTO Terrace Area
Chisel Plow Area
MARIE DELARME WATERSHED
STRATEGY #2
ALLEN COUNTY, INDIANA
Upper Area
N
SCALE
0 1/4 Mile 1/2 Mile
Middle Area
Lower Area
PTO Terrace Area
Chisel Plow Area
MARIE DELARME WATERSHED
STRATEGY #
ALLEN COUNTY, INDIANA
Upper Area
N
SCALE
0 1/4 Mile 1/2 Mile
Middle Area
Lower Area
PTO Terrace Area
Chisel Plow Area
MARIE DELARME WATERSHED
STRATEGIES #5&6
ALLEN COUNTY, INDIANA
Upper Area
N
SCALE
0 1/4 Mile 1/2 Mile
Middle Area
Lower Area
PTO Terrace Area
Chisel Plow Area

(A)

(B)

(C)

(D)

Figure 4. Location of BMPs for alternative strategies.

Table 1. Simulation Results for Alternative Strategies

	Area Affected by BMPs		Total Yield at Watershed Outlet						
Strategy*	PTO	Chisel	Sediment	Total P	Avail. P	Sed. N	Sol. N	Sediment Reduction	Cost**
	(ha)	(ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(%)	($/tonne reduced)
1	0	0	1530	2.1	.6	13	1.0		
2	285	104	650	.8	.2	6	.6	57	34.70
3	85	213	1080	1.5	.3	10	.8	29	22.00
4	91	272	1220	1.6	.4	11	.8	20	35.30
5	0	321	1340	1.8	.4	12	.9	13	7.50
6	0	321	520	.6	.1	4	.4	19	11.60

1. Baseline condition: Fall moldboard plowed, no BMPs.
2. PTO terraces installed where most of the sediment yield was in excess of 2.25 tonne/hectare. In addition, those areas with sediment yield in excess of 1.12 tonne/hectare not benefited by terraces were chisel plowed.
3. PTO terraces installed in the upper 1/3 of the watershed only. All areas with sediment yield in excess of 1.12 tonne/hectare not benefited by terraces were chisel plowed.
4. PTO terraces installed in the lower 1/3 of the watershed only. All areas with sediment yield in excess of 1.12 tonne/hectare not benefited by terraces were chisel plowed.
5. All areas with sediment yield greater than 1.12 tonne/hectare chisel plowed.
6. Same as Strategy 5 except that a storm with 25% lower intensity and total volume was used. The "baseline condition" for this storm gave a total sediment yield of 640 kg/ha.

Cost information was based on 1979 construction costs for PTO terrace systems in Allen County, Indiana. The cost is based on total area benefited (both above and below terraces). The figure used in these calculations was $510.80 per hectare benefited. A 10-year life was assumed, which yielded an annual cost of $51.08 per hectare benefited. The chisel plow was also assumed to have a 10-year life. The average annual cost per hectare, based on the cost of a new plow, was $2.17. Since the "design storm" used in this example produced approximately the annual sediment yield, the cost per tonne of reduced yield at the watershed outlet is, essentially, the annual cost. However, due to simplifying assumptions and unique local conditions, these cost figures should not be considered to be generally applicable to other planning situations. They were included to demonstrate the type of analyses which can be performed.

intense baseline storm was used. This again illustrates the complexity of analyzing NPS pollution and its control.

Evaluation Example

As an example of the use of ANSWERS for interpreting monitored data, let us consider it use in the Black Creek Project (2,3). This project was initiated in late 1972 by EPA to evaluate the contribution of agriculture to pollution of Lake Erie and to determine impacts of selected BMPs on that pollution. The 4900 ha study watershed, located in NE Indiana, is composed of relative heavy soils associated with glacial till and an old glacial lake. The land use is almost entirely agricultural except for a small community of about 500 persons. Its soils and land use distribution are representative of those in the Maumee Basin.

The Allen County Soil and Water Conservation District, with the technical assistance of the Soil Conservation Service, developed a cost-sharing program to encourage installation of appropriate BMPs. Purdue University and the University of Illinois were responsible for monitoring the physical/chemical and biological water quality impacts of installed BMPs. Figure 5 depicts locations at which physical/chemical monitoring has been conducted for periods ranging from 3 to 6 years. An even more extensive network of biological monitoring locations was established.

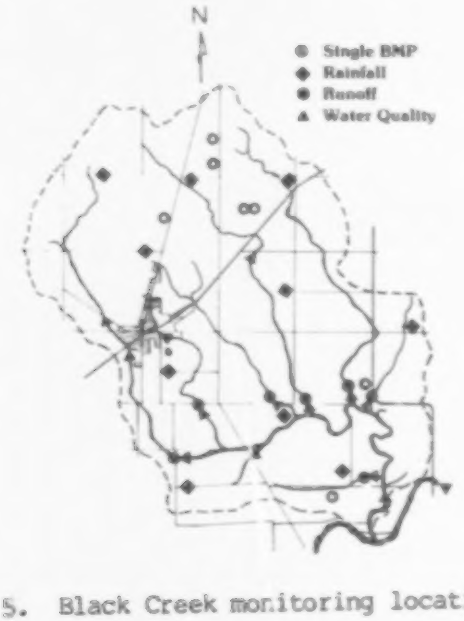


Figure 5. Black Creek monitoring locations.

The Black Creek project has utilized automated, continuous monitoring of stream water conditions near the outlet and at selected subwatershed points for about 5 years. Results from these data were given in another presentation at this seminar. This comprehensive data base has established a reliable indication of water quality conditions within the watershed. However, it is impossible from such data to answer the question: "What have been the benefits from individual classes of BMPs installed during the project?" This is a result of the many uncontrolled factors which influence levels of NPS pollution and the diversity of BMPs, crops and annual management changes which occur on a watershed scale. Such a question can be answered using simulation analysis because it is possible to hypothetically hold all factors, especially hydrologic conditions, constant and change only the applied BMPs.

Figure 6 shows the Black Creek watershed subdivided into three major subwatersheds of approximately equal size. A deliberate effort was made to encourage the installation of BMPs within the western subwatershed. This decision was made to more clearly differentiate BMP impacts and to demonstrate the magnitude of water quality change which was feasible. As a result, a pattern of decreasing practice density occurs as one goes eastward. The initial development of the ANSWERS model was undertaken as a part of the Black Creek Project as it became apparent that monitored data alone was inadequate to quantify impacts of the combinations of installed BMPs.

The BMPs installed within Black Creek were primarily structural in nature: parallel tile-outlet terraces (PTO), field borders, grass waterways and livestock exclusion. Despite the demonstrated water quality benefits of reduced tillage systems, only limited utilization was achieved. This was the result of farmer concern about wetness during the spring on the heavy soils of the area.

The area of land directly affected by installed BMPs ranged from 6 percent in the western subwatershed to less than 2 percent in the eastern subwatershed. ANSWERS simulations, using patterns of land use change and BMPs installed between 1975 and 1978 with assumed constant hydrologic conditions, indicated that BMPs installed within the western subwatershed would reduce annual sediment yield about 30 percent. The reduction for the medium density middle subwatershed was about 20 percent, dropping to only about 10 percent for the minimum treatment level on the eastern subwatershed. Watershed scale impacts from a single installation are also available, but such results are extremely location dependent.

One additional result of general interest was determined. When the installed structural BMPs for the western subwatershed were hypothetically augmented with chisel plowing in selected critical areas, the projected reduction of annual sediment yield was increased to 50 percent.

SUMMARY AND CONCLUSIONS

The manner in which a well-adapted simulation model can be utilized as both a planning and evaluation tool for agricultural non-point source pollution has been demonstrated with two case studies. Such results are

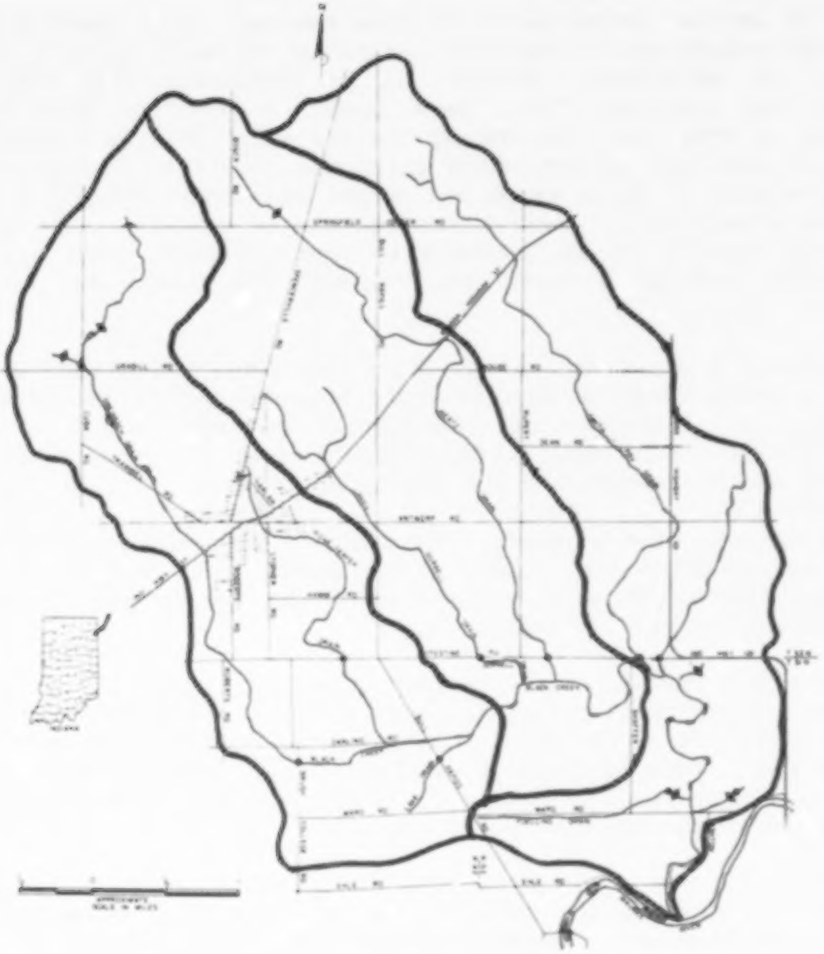


Figure 6. Primary Black Creek subwatersheds.

a direct consequence of using a model which is constructed from established cause-effect relationships between governing processes and is designed to analyze impacts of the type of control measures selected.

A simulation model that analyzes cause-effect relationships in a site specific manner is the only methodology currently available for rational planning or evaluation of storm-induced non-point source pollution control. While additional development work will significantly improve the accuracy and generality of such models, the current state-of-the-art is adequate to justify using them for many applications. Improvement of current models is severely hampered by the scarcity of reliable, continuous monitored data on watershed and individual BMP behavior.

The Marie Delarme case study demonstrated how ANSWERS simulations could be employed in a planning role to quantify BMP impacts and rank site specific BMPs. Maximum benefits from simulation accrue when it is applied at the earliest project planning stages. Furthermore, this example illustrated how a ranking of alternative control strategies is dependent upon the user in the selection of a baseline condition. or unit cost, used and how certain criteria are very dependent upon the baseline condition that is used.

The Black Creek Study has demonstrated that, even with a very comprehensive program, it is impossible to quantify benefits from individual BMPs by monitoring the outlet of a natural, diverse watershed. The ANSWERS model did yield a quantitative estimate of BMP benefits. As anticipated, benefits were estimated to vary with the number and density of installed BMPs. The annual reduction in sediment yield ranged from only 10 percent from the eastern third of the watershed to 30 percent from the western, most densely treated, third. Furthermore, simulation studies indicated that a reduction of 50 percent is feasible if the installed structural BMPs had been augmented with chisel plowing in selected critical areas.

REFERENCES

1. Beasley, D.B. and L.F. Huggins. 1980. ANSWERS User's Manual. Agric. Eng. Dept. Purdue Univ., 55p.

2. Lake, J. and J. Morrison. 1977. Environmental impact of land use on water quality: final report of the Black Creek project--summary. U.S. Envir. Prot. Agency, Region V, Chicago, IL. EPA-905/9-77-007-A. 94 p.

3. Lake, J. and J. Morrison. 1977. Environmental impact of land use on water quality: final report of the Black Creek project--technical report. U.S. Envir. Prot. Agency, Region V, Chicago, IL. EPA-905/9-77-007-B. 274 p.

PRACTICAL USES OF THE ANSWERS MODEL IN BMP PLANNING: AN ALLEN COUNTY EXPERIENCE

by

Daniel McCain*

Other papers in this proceedings discuss the details of the work done in water quality management and ongoing research of planning at the national, regional, or state level. The focus of my presentation will be practical local use of the ANSWERS computer model that is now setting priorities for conservation work as related to water quality in Allen County. At this time, we are past the 5 year EPA funded Black Creek (1972-1977) demonstrational project and well into our second year of applying ASCS Special ACP Water Quality money.

To be successful and get conservation on the land to improve water quality, we've had to involve people--not just agency personnel, but the people that do the farming. Ultimately, it is the farmers who carry out national objectives for conservation. To gain their cooperation, field people have to bring them together on some mutual basis. In the humid midwest (corn belt), that mutual interest centers on drainage basins.

In 1969, when I was assigned to work in Allen County, the emphasis of conservation work in the county--by both the Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS)--was on drainage. More than a decade later, this emphasis has shifted dramatically. SCS and other agencies of the U.S. Department of Agriculture have undergone considerable change in how their appropriations are used, and their programs have also changed. In Allen County the difference has not been due entirely to the earlier Black Creek experience, but I'm certain that many local changes occurred as a result of national trends interacting with our staff, the soil and water conservation district supervisors, and farmers during the 1970's. We have found ourselves on the "cutting edge" with our local adaption of nationally conceived "non-point source" concerns.

After the work in Black Creek was complete, a search was made for other problem areas in the county. On a critical area map, targeted rural watersheds were located that had the worst water quality problems. The result was a list of 13 small watersheds (1,000 to 3,000 acres) we call the "Dirty Baker's Dozen." Using the ANSWERS model and ranking these watersheds according to gross soil loss per acre, the most important critical areas were pinpointed. In 1979 special funds were applied for and received through the Agriculture Conservation Program (ACP) for a water quality project. Most of the $75,000 in ACP funds received in 1979 has gone into one of the 13 target watersheds, a 1,645-acre area called the Brunson project. In 1980, two more critical watersheds were evaluated and the "Dirty Baker's Dozen" was reranked. This year $100,000 is spread into six (6) of the thirteen (13) watersheds.

*District Conservationist, Soil Conservation Service, Ft. Wayne, IN

A primary reason for this special ACP funding was an innovative approach to determine where planning is needed. When a group of people come to us for what they believe is simple-to-define technical assistance with drainage, they don't realize that we're going to try our best to develop their appreciation for water quality improvement, as well as solve their drainage problems. We are doubly fortunate in that the relationships that began emerging with Black Creek in 1972 and that exist among other local decisionmaking groups reflects a strong commitment to attack problems head-on.

Groups we are now working with in the Special ACP Project approach are receptive. The ANSWERS model is a big reason why. Planning with ANSWERS involves the use of computer drawn maps such as the "erosion contours" map. This tool points out "hot-spots" or critical erosion areas identified by location within the watershed. A trained conservationist might wonder why these areas cannot be located through field work instead of using printouts from a computer model. We can, but that's not the point. A computer-drawn map of erosion contours in the watershed gives a focus for meetings with groups of farmers. Talking with them about the map helps them become more receptive to learning where and when erosion occurs because of slope and concentrated runoff.

In meetings with the group, we emphasized the proximity of erodible lands to the drainage outlets. When a conservation planner presents the group with a few conclusions from this fact, farmers can readily visualize where erosion is causing water quality problems. The total sediment yeilds computed by the model represent a net loss of topsoil through the "month" of the watershed.

A 20- by 40-inch blowup of the Universal Soil Loss Equation (USLE) sliderule calculator has been used before several groups. The calculator has not intimidated the groups: by using such visual aids, highly technical matters are comprehensible to farmers. Our partnership with the groups has to be educational--on both sides--to be effective. Taking the group on a field trip to see opportunities and to recognize potential benefits also helps.

In conservation planning sessions with the groups we have tried not to put all our eggs in one basket, for example, with conservation tillage. Success with conservation tillage depends on many variables. It was not possible to persuade many farmers to convert to conservation tillage during the Black Creek era simply because of these variables. For example, climatic variability over a 4-year rotation might bring a wet spring, a dry spring, an early spring, and a late spring. Climate and other variables require the farmer to make daily decisions that can complicate his tillage plans.

Not that I'm negative about conservation tillage--in fact it's the one practice that can touch every acre--but I've seen what can happen when a farmer tries it without fully understanding it. It may require him to adapt his equipment and make other changes. Every spring day the farmer can face a different set of weather conditions, crop prices, operating expenses, and other things which he has no control but on which he must form decisions. Therefore, it is important to offer the farmer conservation alternatives that won't add to his burden of daily decisionmaking. Seen positively, however, conservation tillage is not a burden at all but an investment in wise management that pays off in savings in fuel, labor, time, water, and soil.

Even so, practices such as terraces serve as permanent "reminders" of conservation on the landscape. These practices can be very compatible with conservation tillage; most important, however, they signal a "commitment to conservation" and become symbols of the group's progress in understanding and dealing with erosion and sedimentation. And if nature provides a disastrous spring for tillage, at least part of the conservation system will function.

Permanent conservation practices require the farmer to make fewer decisions, although they won't necessarily be any easier to make than decisions about tillalge. For example, if a farmer wants to construct terraces and waterways and needs financial help, he requests cost-sharing assistance from the ASCS office. SCS provides an engineering plan and gives him a cost estimate, and his thoughts come down to a one time "yes or no" decision. If he decides to go ahead with the practices, a contractor builds them and they become a permanent facility. The only question remaining is whether the farmer will permanently maintain the practices.

In all, then, there are three ways we can tackle cropland erosion problems related to water quality. First, we encourage changes in TILLAGE and in planting techniques. Second, we encourage CROP ROTATIONS that are compatible with the farmer's present tillage system. Or third, we suggest permanent land treatment practices such as TERRACES, which reduce slope length and increase temporary storage capacity for runoff. If the farmer selects any on of these changes--or some combination of them--improved water quality should be the result.

When we targeted critical areas in the Brunson project we had to go after the job from the top of the hill down. We didn't want to repeat an earlier experience in Black Creek; that is, overselling the group on what they were already prepared to request--outlet development. Also, in Black Creek more streambank protection than necessary may have been installed because of the farmers' concern about highly visible streambank erosion. Black Creek findings showed that only about 7 percent of the sediment load entering the Maumee River was caused by streambank erosion. However, the farmers noticed streambank erosion more than they noticed sheet and rill erosion on sloping cropland.

In planing with the groups and in orienting them to the kinds of practices needed, ASCS and SCS can provide farmers with cost sharing and technical help as far down the outlet as necessary to make a properly functioning project. In the Brunson project, individual terrace outlets were safely taken down the watershed through tile beside group grass waterways, and into a protected mutual open outlet. All these practices helped as part of a protective scheme for the critical areas.

It may also be necessary to study the channel far enough through the critical areas to find the unstable segments. In Black Creek, we were most successful with a practice we call "training," that is, putting rock riprap low on the channel banks in unstable soils and installing a 1½- to 2-foot drop structure to lessen channel grade.

From the top of the watershed down, an opportunity and an obligation exists to explain technical alternatives to the farmers. The ANSWERS model is useful for these explanations because it graphically depicts the eroding areas. An overlay of the erosion contours map with an ownership map lets the farmer see whether he has an erosion problem that requires attention. But don't tell him, "Look, you dirty farmer, you're causing all these water quality problems and you're going to have to do something to clean them up." Instead, approach the group in a positive way by showing them the beneficial things that they can do--both as a group and as individuals--to improve water quality and reduce the sedimentation on their neighbors' lands donwstream.

In some cases, the approach to land treatment in the Brunson project was turned 180 degrees from the previous approach in Black Creek, where outlets were usually developed first. In the Brunson project, we started at the top of the watershed by securing commitments from farmers for cropland treatment. Of the $75,000 allocated for the Dirty Baker's Dozen in 1979, ASCS approved $60,000 for cost sharing of group parallel tile outlet (PTO) basin terraces in the Brunson watershed. To make the terraces work, waterways were constructed and outlets developed to handle the metered tile flow from the terraces. Most of the job was completed in 1979. A second smaller group--SOUTHWEST BRUNSON--with some of the same farmers, completed additional terraces and a mutual waterway in the summer of 1980.

The ANSWERS model could prove even more valuable when used with the analysis of BMP's on farms and as a group. The hypothetical watershed (figure 1) and reduction estimates (table 1) illustrate a means of using the ANSWERS model in planning. Perhaps the time will come when the public will buy water quality improvement with "dollars spent for tons saved."

Table 1. Effect of BMPs in reducing sediment

GROUP	INDIVIDUALS	CELLS	PRIMARY BMP APPLICATION	LEVEL (AVE/FARM)		% REDUCTION
				INITIALLY	WITH BMP'S	
A	ALL PLUS	100	OUTLET	1350	675	50%
SUB GROUP B	SAMUELS	20	LIVESTOCK EXCLUS.	1500	700	53%
	SMITH	17	NONE	2000	2000	0%
	FRY	13	NONE	1000	1000	0%
SUB GROUP C	SHARP	6	WATERWAY	700	500	28%
	JONES	14	TERRACES	1000	400	60%
	GREEN	8	TILLAGE	1200	600	50%
	GRAY	10	TERRACES	900	400	55%
	JOHNSON	12	NONE	1200	1200	0%
SUB GROUP D	JONES	14	TERRACES	1000	400	60%
	GREEN	8	TILLAGE	1200	600	50%
SUB GROUP E	GRAY	10	TERRACES	900	400	55%
	JOHNSON	12	NONE	1200	1200	0%

SCS-228 (8-66)

CONSERVATION PLAN MAP

UNITED STATES DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

cooperating with

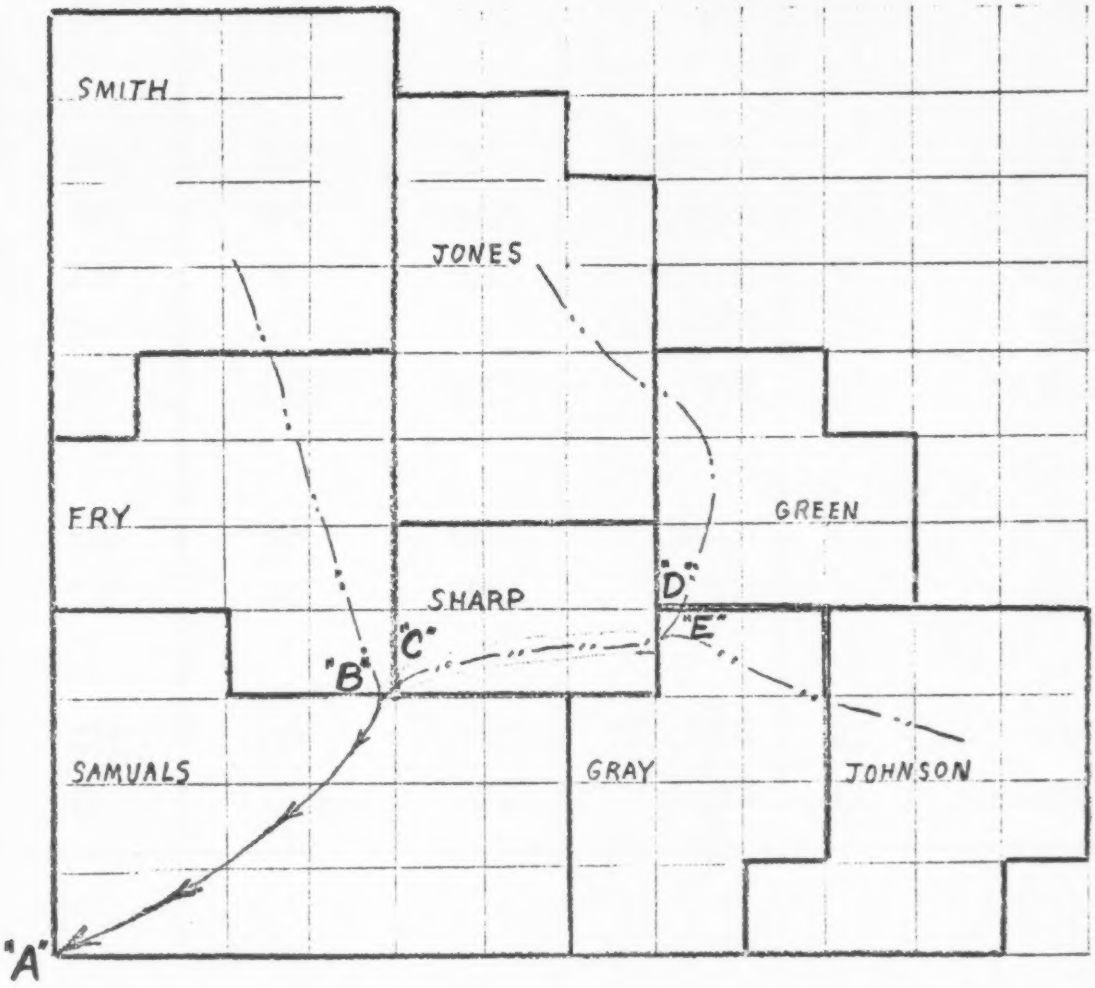
ALLEN COUNTY SWCD

Conservation District

≡ OUR SOIL ★ OUR STRENGTH ≡

Owner HYPOTHETICAL GROUP PROJECT Plan No. ______ Date 9/80
Operator ______ Scale ______ Acres ______ Approximate
______ County, ______ State Photo No. ______

FIGURE 1 - HYPOTHETICAL WATERSHED


SMITH
JONES
FRY
GREEN
SHARP
"D"
"E"
"C"
"B"
SAMUALS
GRAY
JOHNSON
"A"

WATER QUALITY: SEDIMENT AND NUTRIENT LOADINGS FROM CROPLAND

by

D. W. Nelson, D. B. Beasley, S. Amin, and E. J. Monke*

Public Law 92-500 passed in 1972 mandated that each state prepare a water quality management plan which encompasses nonpoint as well as point sources of pollution. In attempting to prepare strategies and/or plans for control of nonpoint pollution, most state and federal planning/regulatory officials became aware that relative little is known about the amounts of water pollutants originating from agricultural land or the effectiveness of techniques to control or minimize pollutant deliveries. Preliminary studies suggested that the most significant water pollutants originating from cropland are sediment, plant nutrients, and pesticides (1).

Although a number of small watersheds (<30 ha) at various locations in the eastern U.S. had been periodically monitored during the past 20 years, no monitoring of a medium size (∿1000 ha) agricultural watershed had been conducted. Furthermore, the effectiveness of soil conservation practices known to reduce erosion on small plots had not been evaluated on a medium size watershed. Therefore, a long term study of the effects of agricultural activities on water quality was started in 1973 on a 5000 ha watershed in Allen County, Indiana. The project was funded under the Great Lakes Program, Region V U.S. Environmental Protection Agency and involved coordinated efforts of the Allen County Soil Conservation District, the Soil Conservation Service, the Agricultural Research Service, Purdue University, and the University of Illinois. The objective of the project was to determine if water quality in the watershed and in the Maumee River could be improved by implementation of a wide range of soil conservation practices in the drainage area. For details of the project consult Lake and Morrison (2).

MATERIALS AND METHODS

Study Area

The 5000 ha Black Creek watershed (Figure 1) was selected for study because it was representative of the soils and land uses prevailing in the Maumee River drainage basin. Table 1 provides information on the soils and land use in the watershed. About two-thirds of the area consists of nearly level lake plain and beach ridge soils, whereas one-third of the area is gently sloping (3-6%) glacial till soils. Land use in the watershed is about 60% row crops, 30% small grain and pasture, and 10% woods, roads, and developed areas. The drainage pattern in the area consists of one natural stream (Black Creek) running from

---

*Professor of Agronomy and Assistant Professor, Research Associate, and Professor of Agricultural Engineering, Purdue University, W. Lafayette, IN 47907. Indiana Ag. Exp. Sta. Jour. Paper No. ______.

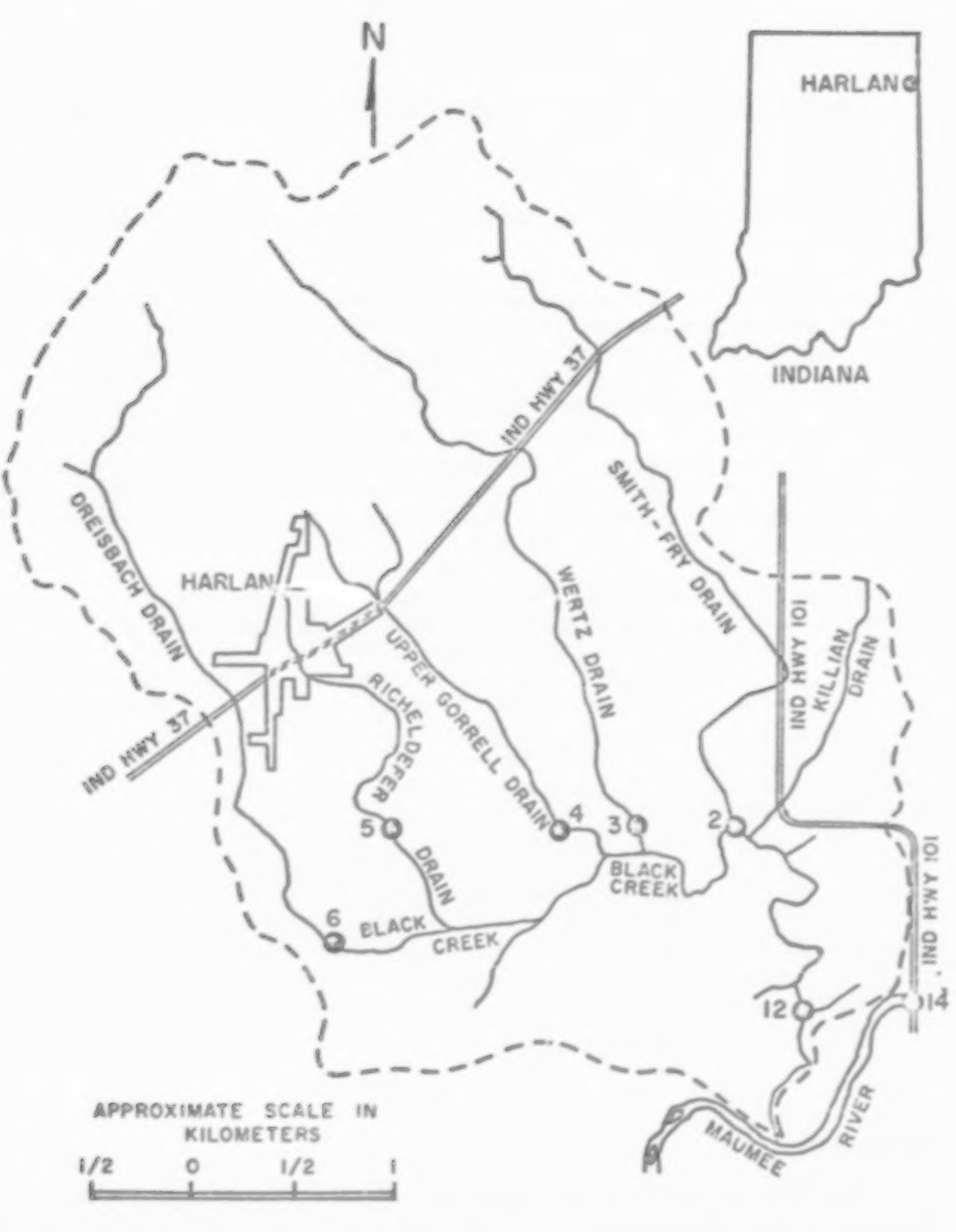

N
HARLAN
INDIANA
IND HWY 37
DREISBACH DRAIN
HARLAN
SMITH-FRY DRAIN
WERTZ DRAIN
UPPER GORRELL DRAIN
RICHELDEFER DRAIN
IND HWY 101
KILLIAN DRAIN
5
4
3
2
BLACK CREEK
6
BLACK CREEK
12
14
MAUMEE RIVER
APPROXIMATE SCALE IN KILOMETERS
1/2
0
1/2
1

Figure 1. Map of the Black Creek study area.

west to east and discharging into the Maumee River (Figure 1). A number of constructed drainage ditches intersecting with Black Creek are used as outlets for surface and tile drains. Most of the lake plain soils in the watershed are tile drained.

Table 1. Characteristics of the Black Creek watershed and two intensively studied drainage areas within the watershed.

Characteristics	Black Creek watershed	Smith-Fry Drain (Site 2)	Driesbach Drain (Site 6)
Drainage area, ha	4950	942	714
Soils:			
Lake Plain & beach ridge	64%	71%	26%
Glacial till	36%	29%	74%
Land use:			
Row crops	58%	63%	40%
Small grain & pasture	31%	26%	44%
Woods	6%	8%	4%
Urban, roads, etc.	5%	3%	12%
Number of homes:	--	28	143

Monitoring Systems

Grab sampling stations were established at 14 sites within the watershed and on the Maumee River to provide weekly data on the quality of water originating from soils and land uses in the drainage area above the site. Automated sample (PS 69) and flow measuring devices were installed at three locations (Sites 2, 6, and 12) in the watershed (Figure 1) to provide continuous flow data and to permit calculation of loadings on a storm or time period basis. Meteorological conditions in the watershed were continuously monitored. A complete hydrometeorological station with automatic data acquisition and remote transmission capabilities was established at Site 6. The amount of rainfall was measured at seven other locations in the watershed and rainwater samples were collected for chemical analysis at two locations.

Temperature and dissolved oxygen concentration of water were measured *in situ* and shortly after collection pH, turbidity, and alkalinity were measured in grab samples. Water samples taken by grab or automated methods were frozen soon after collection, transported to the Water Quality Laboratory at Purdue University and analyzed for suspended solids, NH_4^+-N, NO_3^--N, soluble organic N, sediment-bound N, soluble inorganic P (filtered reactive P), soluble organic P, and sediment-bound P. Pesticides, alkaline earth cations, and heavy metals were measured in selected samples. Methods used for analysis of all samples were those prescribed by the American Public Health Association (3) or the U.S. Environmental Protection Agency (4).

Data Processing

Loadings of sediment and nutrients were calculated by integration of flow and concentration data on a storm, monthly, quarterly, or yearly basis. Flow weighted mean concentrations (monthly basis) were calculated by dividing the monthly load of sediment or nutrient by the monthly volume of runoff. The average total N and P concentrations in suspended sediment were calculated by dividing the monthly sediment-bound N and P loads by the monthly sediment load. The enrichment ratios for total N and P were calculated by dividing the total N and P concentrations in sediment by the average total N and P concentrations in soils present in the drainage area. Linear regression and correlation techniques (5) were used to determine the relationships between monthly or quarterly runoff volume, sediment losses, nutrient losses, and nutrient concentrations in sediment.

RESULTS AND DISCUSSION

Reconnaissance sampling within the watershed revealed that no significant amounts of hexane-soluble pesticides were present in water, sediment, or fish tissue. Specific pesticides evaluated included aldrin, dieldrin, DDT and metabolites, atrazine, trifluralin, and 2,4,5-T (2). Analysis of weekly grab samples established that the dissolved oxygen, temperature, pH, alkalinity, and alkaline earth cations levels exhibited trends which were typical for medium size agricultural watersheds (6). Heavy metals were present in only trace concentrations (6).

Sediment and Nutrient Loads

Table 2 provides information on rainfall, runoff, and sediment lost from the two major drainage areas in the Black Creek Watershed during the period 1975 to 1978. Precipitation was above normal in 1975, below normal in 1976, and near normal in 1977 and 1978. Runoff volumes tended to be highest during years with greatest rainfall, however, the percentage of precipitation appearing as runoff varied over the years (26% in 1975, 17% in 1976, 20% in 1977, 26% in 1978, an average of 22% over 4 years). Sediment discharges from the watershed averaged 895 and 1279 kg/ha for Sites 2 and 6, respectively. However, sediment losses in 1975 were from 4 to 8 times higher than the average of the other three years. Sediment losses during 1977 and 1978 were low (380 to 540 kg/ha) even though rainfall during these years was near normal. This finding suggests that best management practices implemented in the watershed during 1975 and 1976 resulted in reduced sediment losses in subsequent years.

Data on amounts of sediment-bound N and P discharged from the two drainage areas during 1975 to 1978 is also given in Table 2. The quantities of sediment-bound nutrients lost from the drainage areas decreased markedly after 1975, generally in proportion to reductions in sediment loss. Application of best management practices in the watershed was, at least in part, responsible for reductions in amounts of sediment-bound nutrients observed during the course of the study.

Table 2 also provides data on the amounts of soluble nutrients discharged from the two drainage areas during a four-year period. Although the amounts of soluble inorganic P annually discharged from the drainage areas were low (<0.7 kg/ha/year), there is no indication that the amounts lost decreased with time during the study. In fact, there was a marked increase in soluble inorganic P loss during 1978. One explanation for the increase in soluble P loss at Site 6 during 1978 is that large volumes of untreated household wastewater was discharged into the drainage ditches near Harlan during the time an interceptor sewer was being constructed. Previous studies have shown that septic tank effluents were a major source of soluble P measured at Site 6 (7). The amounts of NH_4^+-N, NO_3^--N, soluble organic N, and soluble organic P discharged from the drainage areas each year were directly related to the volume of runoff. Losses of soluble organic P were very low (<0.13 kg/ha/year) except at Site 6 in 1978 where septic tank effluent likely contributed to the load. Soluble organic N losses were significant (0.74 to 2.89 kg/ha/year) during all years at each site and the higher losses measured at Site 6 probably reflect septic tank inputs. Losses of NH_4^+-N were relatively low (0.58-1.82 kg/ha/year) throughout the period of study except for Site 6 during 1978. Septic tank effluents likely were responsible for higher NH_4^+-N losses observed at Site 6 in 1978. The amounts of NO_3^--N in drainage water appeared to be related to amounts of rainfall in the watershed, i.e. losses of NO_3^--N were highest in 1975 and 1977, the two years with highest rainfall. Losses of NO_3^--N were relatively large (average of 12 and 8 kg N/ha/year for Sites 2 and 6, respectively) and likely reflect the fact that the watershed is tile drained and that the soils are maintained in a high state of fertility by applications of manure and inorganic N fertilizers. Although the amounts of NO_3^--N discharged from the watershed were substantial, the annual flow weighted mean NO_3^--N concentration never exceeded the U.S. Environmental Protection Agency drinking water standard (10 mg/l).

The data in Table 2 suggest that adoption of best management practices to control soil erosion has not resulted in a reduction in the discharge of soluble forms of N and P from the watershed. In fact, there is an indication that losses of soluble N and P increased slightly as soil conservation practices were implemented during the study. In future projects some attention should be given to implementation of best management practices which minimize the transport in drainage water of soluble nutrients originating from soils.

The annual discharges of sediment, sediment-bound nutrients, and soluble N from Site 2 (almost all cropland) were similar to those from large river basins and some small watersheds (Table 3). However, the annual sediment losses measured at Site 2 tended to be lower than sediment losses reported for several small (<33 ha) watersheds planted to row crops. There is little sediment deposition in small watersheds, but considerable deposition in the Black Creek area. The soluble inorganic P loadings measured at Site 2 were similar to those reported from both river basins and for small watersheds. Soluble N (NH_4^+-N plus NO_3^--N) loadings at Site 2 were higher than those reported for many small watersheds. This finding likely results from the NO_3^--N in tile drainage water present in the Black Creek watershed, but absent in most of the small watersheds previously studied.

Table 2. Rainfall, runoff, and sediment and nutrient loss occurring in two drainage areas of the Black Creek watershed during the period 1975 to 1978.

Parameter	Site no.	Year				
		1975	1976	1977	1978	Ave.
Rainfall, cm	2 & 6	108	66	96	77	86.8
Runoff, cm	2	29.1	12.4	18.5	18.5	19.6
	6	26.0	10.1	19.4	21.3	19.2
Sediment loss, kg/ha	2	2126	637	435	380	895
	6	3735	384	452	544	1279
Sediment P loss, kg/ha	2	5.24	0.98	1.67	0.65	2.14
	6	4.51	0.73	1.78	0.79	1.95
Sediment N loss, kg/ha	2	31.25	4.82	4.55	6.10	11.68
	6	28.98	2.86	4.71	6.91	10.87
Sol. inorg. P loss, kg/ha	2	0.14	0.06	0.14	0.21	0.14
	6	0.34	0.18	0.47	0.68	0.42
Sol. org. P loss, kg/ha	2	0.11	0.04	0.06	0.08	0.07
	6	0.13	0.04	0.10	0.35	0.16
NH_4^+-N loss, kg/ha	2	1.51	0.60	0.58	0.75	0.86
	6	1.82	0.85	1.30	3.06	1.76
NO_3^--N loss, kg/ha	2	19.01	5.55	15.42	8.27	12.06
	6	11.63	2.39	12.73	5.96	8.18
Sol. org. N loss, kg/ha	2	2.33	0.93	1.10	1.66	1.55
	6	2.51	0.74	1.78	2.89	1.98

Average monthly rainfall, runoff, sediment loss, and nutrient loss values are given in Table 4. Rainfall was reasonably well spread throughout the year with April, June, and August having the highest monthly average amounts. Sediment losses were greatest in February, March, May, and June, whereas sediment losses were very low (<14 kg/ha/month) from July through November. Sediment N and P losses paralleled sediment losses in that the highest discharges of sediment-bound nutrients occurred in May and June and low discharges were observed from July through November. The highest monthly losses of NH_4^+-N, soluble organic N, soluble inorganic P, and soluble organic P were observed in the period February through April. This finding suggests that snowmelt runoff and early spring rains were responsible for significant transport of soluble N and P. Some of the soluble N and P transported likely was leached from residues from the previous crop present on the soil surface at the time of snowmelt. Substantial amounts (>1 kg N/ha/month) of NO_3^--N were transported out of the Site 2 drainage area during February, March, April, June, and December. The finding that relatively high losses of NO_3^--N occurred during months when sediment loss was not high (April and December) suggests that a subsurface flow and tile drainage are major transport means for NO_3^--N in the Site 2 subwatershed.

Table 3. Annual sediment and nutrient loading from selected agricultural watersheds in the United States.

Watershed		Land Use	Pollutants transported					Reference
Location	Size		Sediment	Sed. P	Sol. P[a]	Sed. N	Sol. N	
	ha		kg/ha/year					
Ohio (Maumee River Basin)[d]	1.639×10^6	Mixed	950	1.53	0.29	--	13.4	9
Ohio (Portage River Basin)[d]	111×10^3	Mixed	658	0.84	0.30	--	13.1	9
Ohio (Plot 111)[d]	3.2	Soybeans	--	1.09	0.13	--	12.3	9
Mich. (Ave. of Plots)[e]	0.8	Row Crops	12940	--	0.71	25.8	2.8	10
Georgia (Watershed P2)[f]	1.3	Corn	6022	--	--	10.3	3.7	11
Iowa (Watershed 2)[g]	3.3	Corn	9980	--	0.09	14.8	1.4	12
Oklahoma (Watershed C3)[h]	17.9	Cotton	3900	5.6	1.1	9.7	1.9	13
N. Carolina (Watershed 2)[i]	1.5	Corn Wheat Pasture	--	--	0.27	--	12.08	14
Ohio (Maumee)[j]	-	Cropland	80-5100	0.7-4.3	0.05-0.3			1
Michigan (Mill Creek)[j]	-	Cropland	20-70	0.1-0.3	0.1 -0.3	4.3-10[c]		1
Ag Watersheds[j]	-	Cropland	400-800	0.6-0.9	0.3 -0.4	16-31[c]		1

a, Sol. P is soluble inorganic P (filtered reactive phosphate); b, Sol. N is $(NH_4^+\text{-}N + NO_3^-)\text{-}N$; c, Sediment-bound and soluble N combined; d, Average of data from 1975-1976; e, Average of data from 1974-1975; f, Average of data from 1973-1975; g, Average of data from 1969-1975; h, Average of data from 1966-1976; i, Average of data from 1968-1972; j, Average of two years data from 1975-1977.

Table 4. Average monthly rainfall, runoff, and sediment and nutrient losses from the Site 2 drainage area during 1975-1978.

Month	Rainfall	Total runoff	Sediment lost	NH_4^+-N lost	NO_3^--N lost	Sediment N lost	Sol. inorg. P lost	Sediment P lost
	cm		kg/ha					
Jan.	3.0	1.16	30	0.05	0.94	0.33	0.004	0.050
Feb.	4.7	2.66	167	0.18	1.51	1.10	0.020	0.317
Mar.	7.5	5.38	109	0.21	2.87	1.15	0.049	0.243
Apr.	10.4	3.19	80	0.14	2.34	1.49	0.019	0.209
May	8.0	1.64	236	0.11	0.82	3.54	0.008	0.522
June	10.9	1.86	168	0.07	1.26	2.82	0.008	0.414
July	5.2	0.18	8	0.01	0.14	0.07	0.002	0.016
Aug.	10.9	0.13	2	0.00	0.02	0.01	0.001	0.004
Sep.	7.2	0.43	13	0.01	0.16	0.10	0.004	0.033
Oct.	4.9	0.14	1	0.00	0.02	0.01	0.000	0.002
Nov.	5.7	0.40	9	0.02	0.13	0.12	0.002	0.039
Dec.	5.6	2.44	72	0.08	1.87	0.87	0.023	0.287
Total	84.0	19.8	895	0.88	12.08	11.99	0.140	2.174

Average Monthly Flow Weighted Mean Concentrations

Average monthly flow weighted mean suspended solids and nutrient concentrations are given in Table 5. Suspended solids and sediment-bound nutrients concentrations were highest in February, May, and June and lowest in March, August and October. Fortunately, the poorest water quality from solids and insoluble nutrient standpoints occurred during the annual period of highest flows. Soluble organic N concentrations were reasonably stable over the year varying from 0.56 to 0.95 mg/l. Highest soluble organic N concentrations were observed in January and September. Ammonium N concentrations were highest in February and May and lowest in August and October. Low NH_4^+-N concentrations in late summer may reflect assimilation by the profuse algae and aquatic weed growth present in the ditches from August to October. Nitrate N concentrations were very high (>7.5 mg/l) during January, July, and December. Relatively low NO_3^--N concentrations (<2 mg/l) were observed during August and October when tile drains were not running and little water was present in the ditches. Soluble inorganic P levels exceeded 0.09 mg/l in March, July, September, and December. Only October had a flow weighted mean soluble inorganic P concentration less than 0.01 mg/l. The fact that inorganic P concentrations remained relatively high throughout the summer is surprising in light of the algae and weed growth in the stream. One possible explanation is that sediment present on the stream bed maintained the inorganic P level in solution by equilibrium processes. Soluble organic P concentrations were relatively constant over the year, although the highest concentrations (0.08 mg/l) were measured in August and the lowest level (0.007 mg/l) was observed in October.

Table 5. Average monthly flow weighted mean sediment and nutrient concentrations in Site 2 drainage water during 1975-1978.

Month	Suspended solids	NH_4^+-N	NO_3^--N	Sol. org. N	Sediment N	Sol. inorg. P	Sol. org. P	Sediment P
	mg/1							
Jan.	259	0.43	8.10	0.95	2.84	0.034	0.034	0.431
Feb.	628	0.68	5.68	0.75	4.14	0.075	0.038	1.192
Mar.	203	0.39	5.35	0.82	2.14	0.091	0.035	0.452
Apr.	251	0.44	7.34	0.72	4.67	0.060	0.041	0.655
May	1439	0.67	5.00	0.79	21.59	0.049	0.030	3.183
June	903	0.38	6.77	0.75	15.16	0.043	0.054	2.226
July	444	0.56	7.78	0.56	3.89	0.111	0.056	0.889
August	154	0.08	1.54	0.77	0.77	0.080	0.080	0.308
Sep.	302	0.23	3.72	0.93	2.33	0.093	0.023	0.767
Oct.	71	0.07	1.43	0.71	0.71	0.007	0.007	0.143
Nov.	225	0.50	3.25	0.75	3.00	0.050	0.025	1.925
Dec.	295	0.33	7.66	0.62	3.57	0.094	0.029	1.175
Overall	452	0.44	6.11	0.76	6.06	0.071	0.036	1.099

Nutrient Concentrations in Sediment

The average monthly total N and P concentrations in suspended stream sediments and nutrient enrichment ratios for the Site 2 subwatershed are given in Table 6. The four-year average total N and total P concentrations in suspended sediment were 1.340 and 0.242%, respectively. Sediment transported during April and June had the highest (> 1.6%) total N concentrations, whereas sediment discharged in February and August had the lowest (< 0.7%) total N contents. Total P concentrations in sediment did not vary greatly over the course of the year, however, sediment discharged in November had the highest P content (0.433%) and sediment transported in January had the lowest (0.167%) concentration.

Table 6. Average monthly enrichment ratios and total N and P concentrations in suspended sediment in drainage water collected at Site 2. (All data calculated from average monthly loadings).

	Nutrients in sediment		Nutrient enrichment ratio	
Month	Total N	Total P	Total N[a]	Total P[b]
	---------- % ----------			
Jan.	1.100	0.167	6.6	2.5
Feb.	0.659	0.190	3.9	2.8
Mar.	1.055	0.223	6.3	3.3
Apr.	1.863	0.261	11.1	3.8
May	1.500	0.221	9.0	3.3
June	1.679	0.246	10.0	3.6
July	0.875	0.200	5.2	2.9
Aug.	0.500	0.200	3.0	2.9
Sep.	0.769	0.254	4.6	3.7
Oct.	1.000	0.200	6.0	2.9
Nov.	1.333	0.433	8.0	6.4
Dec.	1.208	0.299	7.2	4.4
Overall	1.340	0.242	8.0	3.6

a Average total N concentration in drainage area soils was 1670 μg/g.

b Average total P concentration in drainage area soils was 680 μg/g.

The four-year average total N and total P enrichment ratios were 8.0 and 3.6, respectively. Highest total N enrichment was observed in sediment transported in April and June. Sediment discharged in November had the highest total P enrichment ratio although the ratio did not vary greatly over the course of the year.

Relationships Between Runoff, Sediment Loss and Nutrient Loss

Table 7 provides data on the degree of relationship between runoff, sediment loss, and nutrient losses from the Site 2 drainage area over the period 1975 to 1978. Data from both monthly and quarterly periods were used in the correlation studies. Losses of NH_4^+-N, NO_3^--N, soluble organic N, and soluble organic P were highly correlated ($r^2 = >.79$) with the total volume of runoff when both quarterly and monthly data was used (Table 7, Figures 2, 3, 4, 5,). Soluble inorganic P losses were correlated ($r^2 = .78$ for monthly data) with total runoff, however, losses of sediment and sediment-bound nutrients were not correlated with total runoff.

Table 7. Relationship between total runoff, sediment loss, and nutrient losses from the Site 2 drainage area during 1975-1978.

Variable 1	Variable 2	Quarterly data	Monthly data
		- Correlation Coeff., r^2 -	
Total runoff	Sediment loss	0.56	0.38
Total runoff	NH_4^+-N loss	0.89	0.79
Total runoff	NO_3^--N loss	0.81	0.81
Total runoff	Sol. org. N loss	0.96	0.95
Total runoff	Sediment N loss	0.44	0.31
Total runoff	Sol. inorg. P loss	0.61	0.78
Total runoff	Sol. org. P loss	0.92	0.92
Total runoff	Sediment P loss	0.49	0.33
Sediment loss	NH_4^+-N loss	0.64	0.47
Sediment loss	NO_3^--N loss	0.44	0.26
Sediment loss	Sol. org. N loss	0.50	0.31
Sediment loss	Sediment N loss	0.95	0.92
Sediment loss	Sol. inorg. P loss	0.12	0.14
Sediment loss	Sol. org. P loss	0.67	0.38
Sediment loss	Sediment P loss	0.94	0.93
Sediment loss	Total N in sediment	0.07	0.16
Sediment loss	Total P in sediment	0.00	0.00
Sediment N loss	Sediment P loss	0.95	0.91
Sol. org. N loss	Sol. org. P loss	0.93	0.93
Sediment N loss	NH_4^+-N loss	0.52	0.37
Sediment N loss	NO_3^--N loss	0.36	0.22
Sediment P loss	Sol. inorg. P loss	0.09	0.10

Losses of sediment-bound nutrients were highly correlated ($r^2 = >.92$) with sediment loss (Table 7, Figures 6 and 7). However, losses of NH_4^+-N, NO_3^--N, soluble organic N, soluble inorganic P, and soluble organic P were not correlated with sediment loss. Loss of sediment N was highly correlated ($r^2 = >.91$) with sediment P transport as was soluble organic

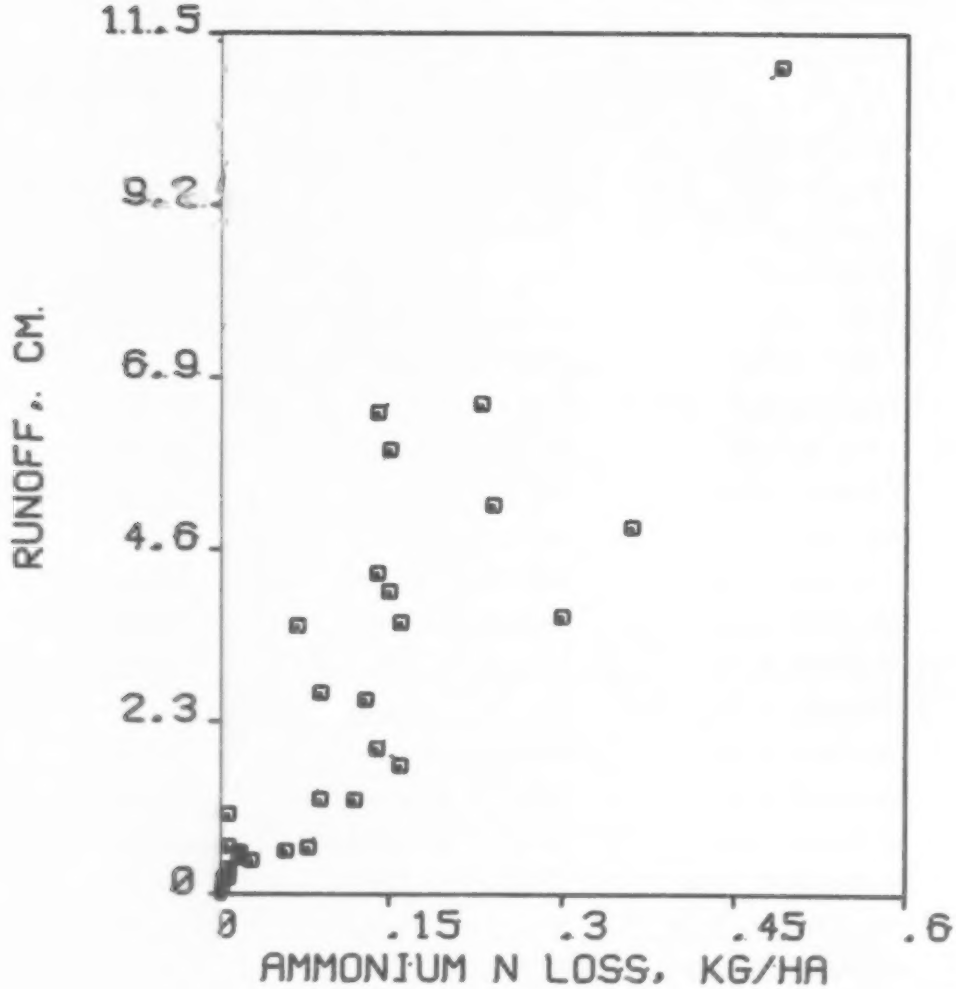


Figure 2. Relationship between monthly runoff and ammonium N losses over the period 1975 to 1978.

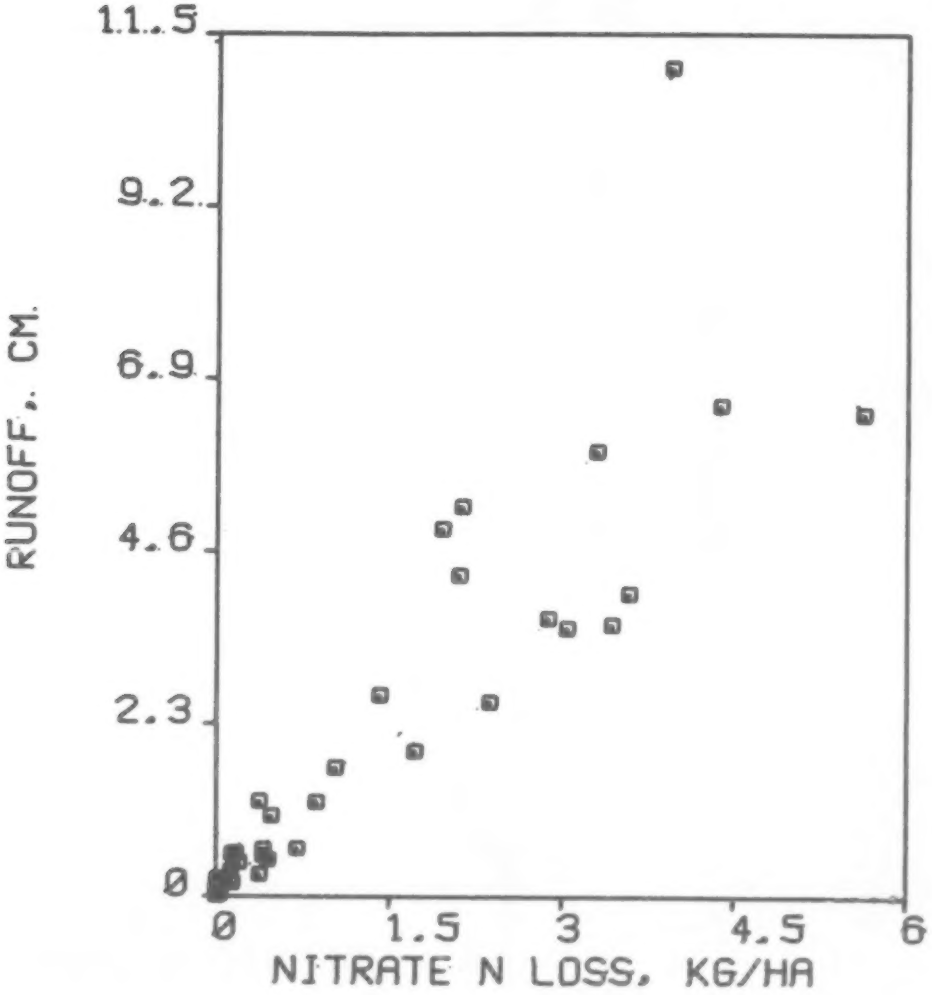


Figure 3. Relationship between monthly runoff and nitrate N losses over the period 1975 to 1978.

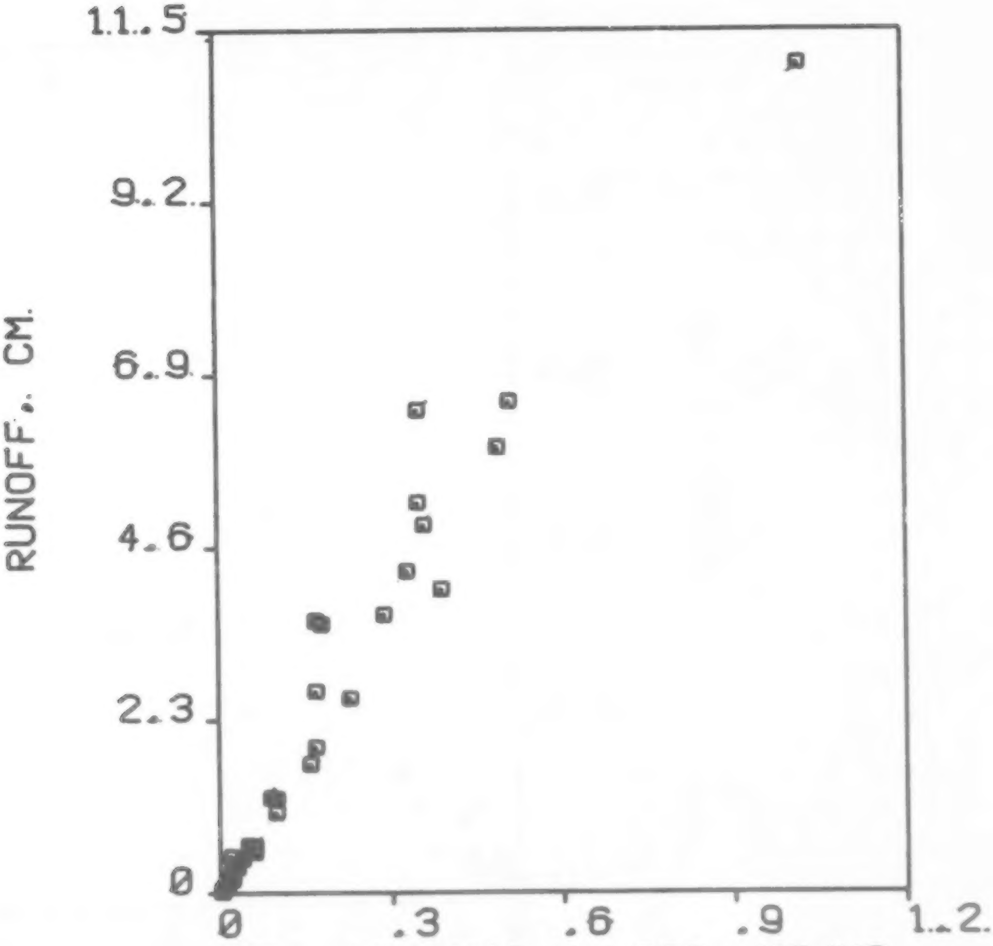


Figure 4. Relationship between monthly runoff and soluble organic N losses over the period 1975 to 1978.

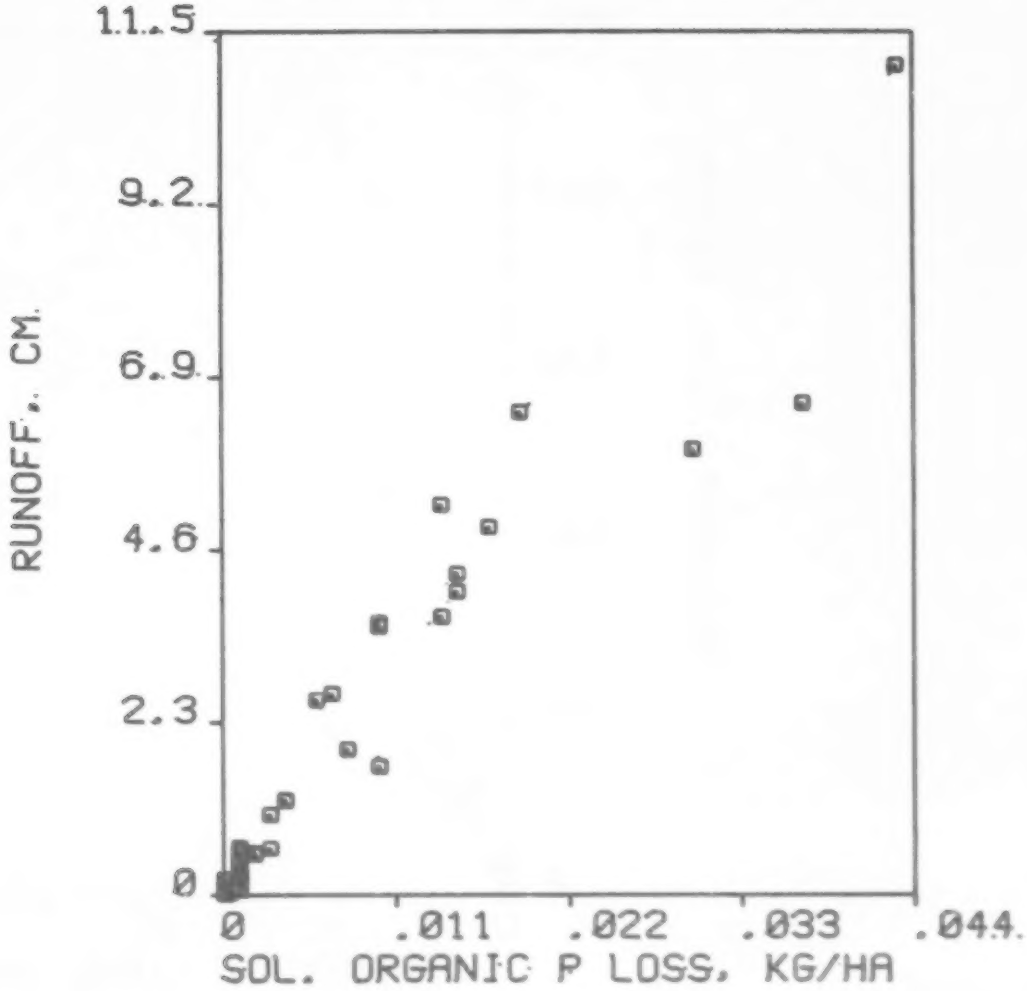


Figure 5. Relationship between monthly runoff and soluble organic P losses over the period 1975 to 1978.

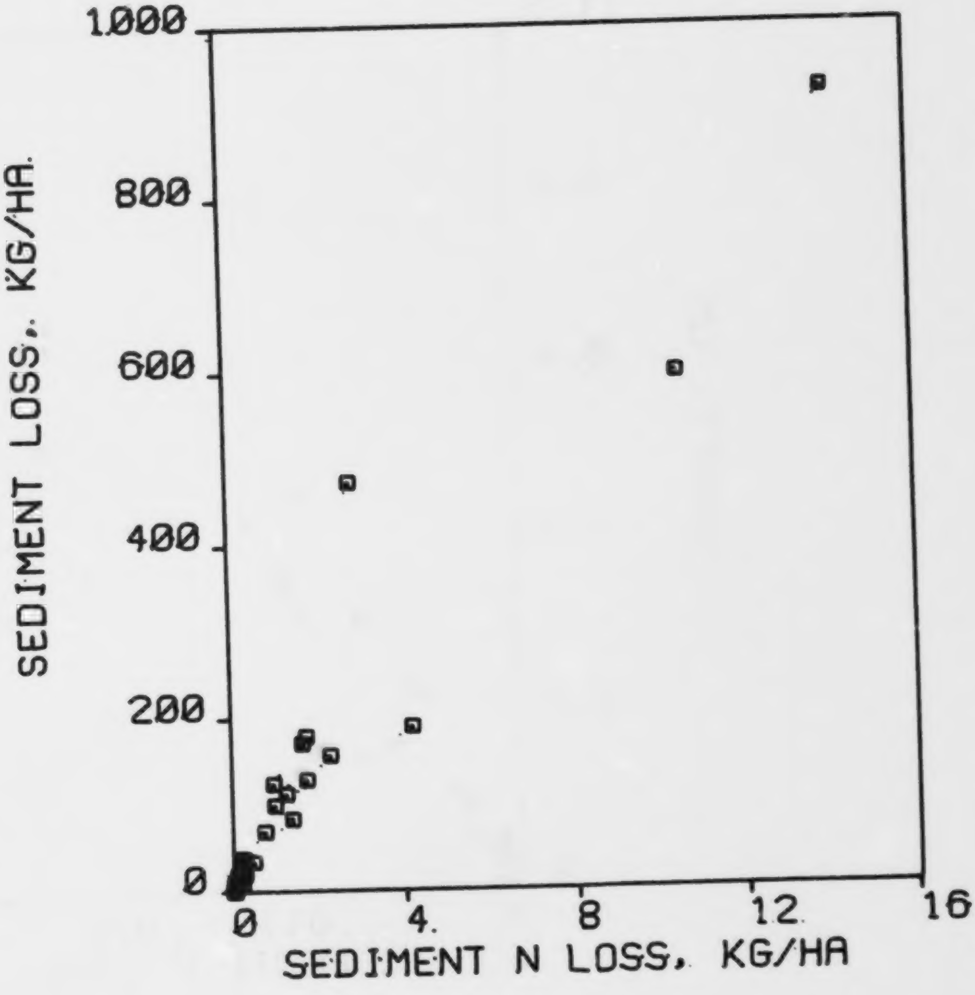


Figure 6. Relationship between monthly sediment losses and sediment-bound N losses during the period 1975 to 1978.

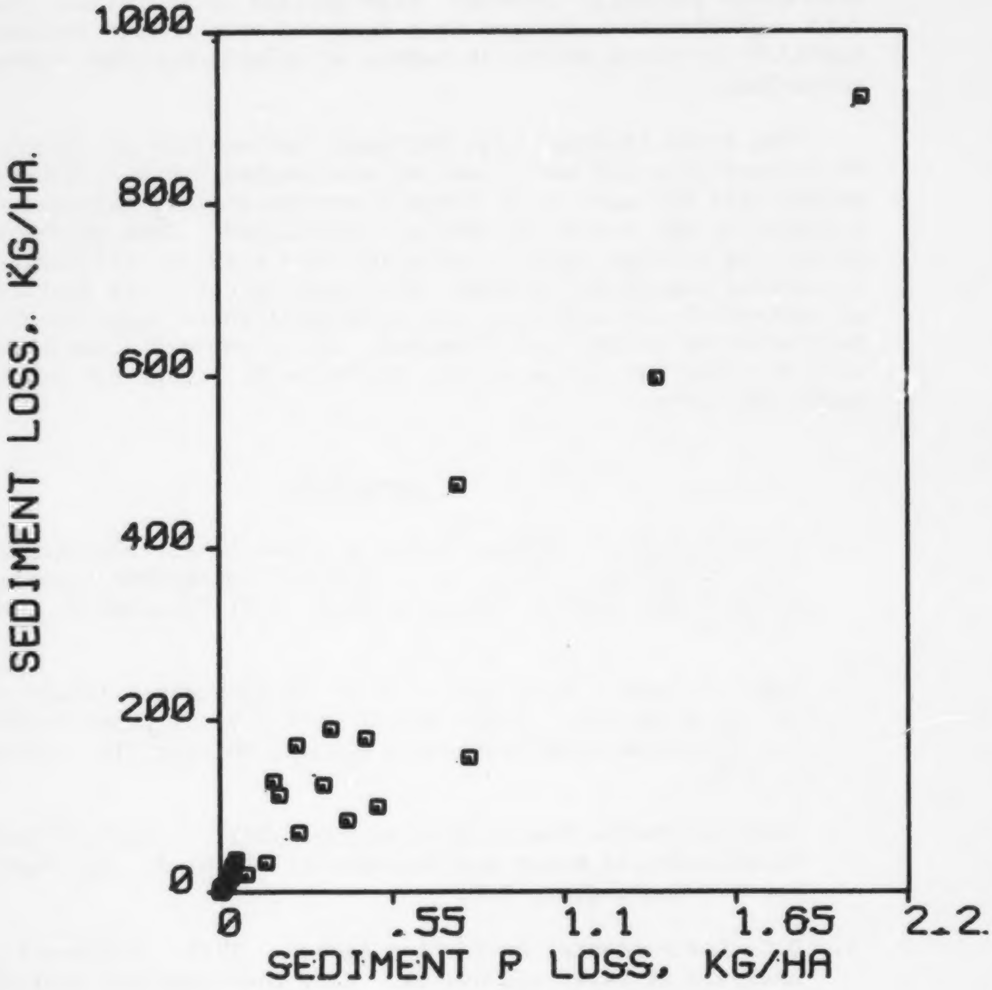


Figure 7. Relationship between monthly sediment losses and sediment-bound P losses during the period 1975 to 1978.

N loss with soluble organic P transport. Ammonium N and NO_3^--N loss were not correlated with sediment N loss. Soluble inorganic and organic P losses were not correlated with sediment P transport.

These findings suggest that monthly or annual loadings of NH_4^+-N, NO_3^--N, soluble organic N, soluble inorganic P, and soluble organic P leaving a watershed can be approximated by multiplying the annual flow weighted mean concentrations by the volume of runoff during the period. This procedure predicted the four-year average monthly loadings with reasonable accuracy. However, when applied to individual year monthly data significant deviations from observed values were obtained. This approach may prove useful in models of soluble nutrient transport from watersheds.

The above findings also indicate that monthly or annual loadings of sediment-bound N and P leaving a watershed can be estimated by multiplying the mean total N and P concentrations, respectively, in sediment by the amount of sediment discharged. This procedure predicted the average monthly sediment-bound nutrient discharges with reasonable accuracy. However, when used to calculate monthly losses of sediment-bound nutrients for individual years significant differences from measured values were obtained. It is apparent that this approach will be valid for use in models which predict transport of sediment-bound nutrients.

REFERENCES

1. International Reference Group on Great Lakes Pollution from Land Use Activities. 1978. Environmental management strategy for the Great Lakes system. International Joint Commission, Windsor, Ontario.

2. Lake, J. and J. Morrison. 1977. Environmental impact of land use on water quality. Final report on the Black Creek Project (summary). U.S. Environmental Protection Agency, Chicago, IL. EPA-905/9-78-001. p. 3-9.

3. American Public Health Association. 1971. Standard Methods for Examination of Water and Wastewater. 13th ed. Am. Public Health Assoc., Washington, D.C.

4. U.S. Environmental Protection Agency. 1971. Methods for Chemical Analysis of Water and Wastes. U.S. Environmental Protection Agency, Cincinnati, Ohio. 16020---07/71.

5. Steel, R.G.D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York. 482 p.

6. Nelson, D. W. and D. B. Beasley. 1978. Quality of Black Creek drainage water: Additional parameters. In Environmental impact of land use on water quality-supplemental comments. U.S. Environmental Protection Agency, Chicago, IL. EPA-905/9-77-077-D. p. 36-83.

7. Nelson, D. W., E. J. Monke, A. D. Bottcher, and L. E. Sommers. 1979. Sediment and nutrient contributions to the Maumee River from an agricultural watershed. In R. C. Loehr (ed.). Best Management Practices for Agriculture and Silviculture. Ann Arbor Science, Ann Arbor, MI. p. 491-505.

8. Logan, T. J. and R. C. Stiefel. 1979. Maumee River pilot watershed study. Watershed characteristics and pollutant loadings, Defiance Area, Ohio. U.S. Environmental Protection Agency, Chicago, IL. EPA-905/9-79-005-A. 135 p.

9. Ellis, B. G., A. E. Erickson, and A. R. Wolcott. 1978. Nitrate and phosphorus runoff losses from small watersheds in Great Lakes Basin. U.S. Environmental Protection Agency, Athens, GA. EPA-600/3-78-028. 84 p.

10. Langdale, G. W., R. A. Leonard, W. G. Fleming, and W. A. Jackson. 1979. Nitrogen and chloride movement in small upland Piedmont watersheds. II. Nitrogen and chloride transport in runoff. J. Environ. Qual. 8:57-63.

11. Alberts, E. E., G. E. Schuman, and R. E. Burnell. 1978. Seasonal runoff losses of nitrogen and phosphorus from Missouri Valley loess watersheds. J. Environ. Qual. 7:203-208.

12. Menzel, R. G., E. D. Rhoades, A. E. Olness, and S. J. Smith. 1978. Variability of annual nutrient and sediment discharges in runoff from Oklahoma cropland and rangeland. J. Environ. Qual. 7:401-406.

13. Kilmer, V. J., J. W. Gilliam, J. F. .utz, R. T. Joyce and C. D. Eklund. 1974. Nutrient losses from fertilized grassed waterways in western North Carolina. J. Environ. Qual. 3:214-219.

THE VARIETY OF ON-SITE TREATMENT SYSTEM FAILURE

by

A. E. Krause*

OUTLINE

Although there are numerous and very real problems of on-site system failure, its presumed but unproven presence has been the justification for a wide variety of centralized treatment systems, some of doubtful utility. New sensing mechanisms and a variety of on-site studies have helped to allow a broader and deeper understanding of this phenomenon.

A. Three Caveats

1. The subject involves the limitations of a wide range of systems, including privies, cesspools, drywells, septic tanks and fields, and even holding tanks.

2. It is important to distinguish between individual and collective failure impact. Individual malfunctions can be found in any large group of systems; They are very different from area-wide health hazards, such as contamination of an aquifer.

3. A functional failure need not mean the presence of a condition that the homeowner can clearly identify; in area of porous soils many kinds of failure may occur without visible evidence.

B. Variety of Failures

1. Surface (Clogging Mat) Failures and Overland Flows.
   There failures are usually associated with clogging mat formation. They may be complicated by tight soils or hydraulic system overload, including external flooding. They may also be caused or affected by quality of construction, suffering from soil compression or irregular pipe slopes. Principal manifestations include surface ponding, system backup, or overland flows to lakes and streams. Principal impacts include lake or stream nutrient enrichment, pathogenic contamination, and other public health problems.

2. Groundwater Failures.
   These are most common on soils of medium to high porosity, and are not usually associated with clogging mat formation. Since the groundwater effluent plume often moves along the surface of the aquifer, its effects are greatly complicated by the direction and speed of groundwater flow. One good example of this situation is Otter Tail Lake, in Minnesota, where effluent plumes from numerous sateliite lakes were moving up to a mile through porous soils to enrich the large central lake.

---

* Physical Scientist, Technology Section, Water Division, U.S. Environmental Protection Agency, Chicago, Illinois

Manifestations and impacts of groundwater failures include localized lakeshore enrichment, algal growth (particularly at point of plume entry) and situational well contamination(where the well may lie in the path of the effluent plume.

3. Special situation or Elective Failures
These include such things as direct tile drainage, straight pipes to streams and "midnight pumpout" of holding tanks-- failures by design. It also includes the relatively uncommon contamination of an entire aquifer by excessive on-site system loading. One of the best-known examples of such a failure is found in Central Long Island, where high density use of cesspools and drywells has rendered an entire aquifer unusable due to nitrate contamination.

C. Pollutants and Impacts

1. Nitrogen.
The various forms of effluent nitrogen are soon converted to the form of nitrates. Nitrates are one of the most significant pollutants in cases of well contamination, causing methemoglobinemia (blue baby syndrome) in concentrations over 10 mg/l. Nitrates are of great importance for high density aquifer contamination, as on Long Island, and are also of marginal significance to lake and stream enrichment. The great bulk of normal effluent nitrogen loading comes from human liquid wastes. There is little or no nitrogen removal in conventional on-site systems

2. Phosphorus.
Phosphorus has little or no direct public health impact, but is well known as a major factor in lake and stream enrichment. It can trigger algal growths, particularly at the entrance point of a groundwater effluent plume. Soil conditions, particularly alkaline soils high in carbonates, can allow a high level of phosphorus removal. Preliminary evidence suggests this may even occur under saturated soil conditions.

3. Pathogens.
Bacteria and viruses usually enter bodies of water through overland flow; bacterial and viral well contamination is often associated with defective well construction and overland flow. Normally any reasonable amount of soil will allow a high degree of adsorbition onto the surface of soil particles.

4. Miscellaneous
BOD and suspended soilds are almost unimportant in relation to on-site treatment except in cases of direct or overland flows. Suspended solids may of course play an important role in causing surface failures.

Other pollutant roles remain to be defined; for some lakeshore algae vitamin B-12 may play as important a role as phosphorus. USEPA Region V (in its Rural Lakes Generic EIS) has some important studies underway.

D. Failure Sensing Methods

1. Interview and Inspection.
This approach, sometimes quite costly, has been the most common one in the past. The classic rhodamine dye test can be reliable for detecting tile field, straight pipe and some overland flows. The door-to-door interview survey is relatively cheap, and even when residents are not completely candid, can produce a useful profile of water consumption and hydraulic loading.

2. Aerial Photography.
   Color and color/infrared aerial photography can provide a good, quick, and relatively cheap survey of conventional surface failures of septic systems and drywells. The photographs should be taken at a height not exceeding 6000 feet, at a time of limited tree cover (early spring or late fall), about five days after the last rainfall. Under these conditions the method can be very effective, sometimes even showing the cause of the failure. It will have a relatively limited value where surface-type failures are uncommon.

3. Septic Leachate Detector ("Septic Snooper")
   This device monitors conductance and ultraviolet fluorescence to detect the actual entrance point of an effluent plume reaching a stream or lake. It uses a wand-type probe and pump to vacuum up water from near-shoreline bottoms for continuous analysis by the instrument, which is normally carried in a small boat. The leachate detector is very effective if properly used (wind velocity should not exceed 5 miles per hour), and has detected some unique situations not accessible through other methods. It has also made possible evaluations and refinements of conventional lake and stream models to reflect actual contributions and loading from on-site treatment systems. This is because, once the plume entry point is known, spot samples can be taken from the lake or (using a portable well point) from the groundwater itself. Miscellaneous uses of the device include quick cheap screening of of drinking water samples for marginal septic effluent contamination.

4. Groundwater Flow Meter.
   This device uses small heat pulses to provide a three dimensional readout of groundwater flow direction and speed, when lowered into the water table. It does this in about three minutes. In soils with possible rock or other inclusions, multiple measurements are needed.

   It is thus possible to have frequent and very site-specific measurements of groundwater flow direction. When used in concert with a leachate detector the flow meter allows tracking of individual effluent plume back to their sources. On old construction it shows the possible direction from which well contamination may be coming. One new construction it allows the treatment system to be placed "downstream" from the well; with a filter field the long axis can be placed perpendicular to the groundwater flow, minimizing effluent concentration at any one point.

E. Results

Using the new sensing approaches it is now possible and cost-effective to determine which of a group of on-site treatment systems may be causing water quality problems, and if an areawide problem actually exists. On seven sample rural lake environmental impact statements (copies available on request) it proved possible to cut treatment costs by an average of two thirds (over a twenty year period) using on-site treatment where appropriate.

In responding to identified system failures there are literally dozens of alternatives available, including: on-site repair, mound systems, cluster systems; field dosing; water conservation and flow reduction, and greywater/blackwater separation. In addition modular combination of these alternative may useful; this was the case on most of the seven lake projects and the recent Waynesville, Illinois facilities plan (recently approved for Step 2+ 3 funding).

F. Work in Progress

The Environmental Engineering Branch of the USEPA Region V Water Division has several projects now underway that may help to further understanding of the problems and appropriate responses to on-site system failure. Among these are:

1. Soil Map Reinterpretation.
   Existing U.S. Department of Agriculture soil map interpretations are being revised. Instead of the simple four-way hazard system for conventional tanks and filter fields, there will be a flexible rating system for a variety of on-site treatment approaches, together with an estimate of the mitigative measures needed (with their approximate cost) to overcome the soil limitation. This work, which will first be completed for ten northern Indiana counties, will allow a much more flexible use of the existing SCS soil surveys.

2. Water Conservation.
   On several dozen presently failing on-site systems in northern Indiana, USEPA has contracted with the State of Indiana and Purdue University to install advanced water conservation and flow reduction devices (two-quart flush toilets, two quart per minute air compressor shower heads, front-loading washing machines) to monitor the exact effect on such devices on effluent quality, and to find just how far water conservation can go in rehabilitating failed systems, especially surface failures.

3. Greywater/Blackwater Separation.
   On other failing Indiana system, especially those with groundwater contamination problems, the same team will install a new kind of greywater/blackwater separation. This uses an extremely low volume flush toilet (two quarts to one cup per flush) together with a holding tank for the toilet wastes only. The system require pumping at interval of six months to two years and results in at least an 80 per cent reduction in nitrate loading to groundwater.

4. Generic Rural Lakes Environmental impact Statement.
   This document will use the seven rural lake impact statements, among others, to assess wastewater planning techniques and sensing methods to produce a cookbook for rural on-site wastewater planning, particularly for rural lake areas.

For information on this and other work in progress, as well as copies of forthcoming papers, please write U.S. Environmental Protection Agency, Region V, Environmental Engineering Branch (5WEE), 230 South Dearborn, Chicago, Illinois 60604.

MILL CREEK PILOT WATERSHED STUDY ON
PESTICIDE FATE IN AN ORCHARD ECOSYSTEM:
DEVELOPMENT AND PRESENTATION OF THE EXPERIMENTAL DATA BASE

by

M. J. Zabik, J. J. Jenkins

R. Kon, L. Geissel[a] and Erik Goodman[b]

a Pesticide Research Center, Michigan State University, East Lansing, Michigan.

b Department of Electrical Engineering and Systems Science, Michigan State University, East Lansing, Michigan.

INTRODUCTION TO MILL CREEK STUDIES

A study of Mill Creek, a subwatershed of the Grand River basin was begun in 1974 as part of the Task C Pilot Watershed Studies of PLUARG. Mill Creek represents a watershed typical of the large fruit growing region of southwestern lower Michigan. Since fruit orchard farming utilizes some of the most intensive pesticide application rates of any agricultural practices in the Great Lakes Basin, it seemed particularly appropriate at the initiation of these studies to emphasize pesticide transport processes. Studies of nutrient exports were also included but not emphasized.

The pesticide transport process can be divided into two categories: (1) pesticide transported in solution, and (2) pesticide adsorbed to particulate matter and convected along with the sediment load of the stream. This distinction is necessary if one is to accurately identify the source of the problem.

The removal and subsequent transport of agricultural non-point source pollutants are directly related to the rainfall-runoff process. Overland flow is responsible for the initial movement of pollutants from the land surface to the stream. Once in the stream, the pollutant may be transported considerable distances by the stream flow. In the particular case of pesticides the quantity transported is related to the solubility and adsorptive characteristics of the pesticide considered. The translocation of pesticides that are adsorbed to or coated on sediment particles depends on the many variables influencing the capability of a stream to transport sediment, whereas those that are water soluble will be convected in amounts that are directly proportional to their concentration level and the stream discharge.

In view of the above description of the processes responsible for the transport of pesticides, the major objective of our research effort was to determine the relative amount of pesticide transported on the suspended solids and in solution. As a result of such a determination it would then be possible to ascertain the magnitude and source of this non-point source problem.

Description of the Study Area

The Mill Creek watershed is located in midwestern lower Michigan. It includes Cranberry Lake and watershed. Mill Creek originates from Cranberry Lake at the Ottawa-Kent County line and flows southeasterly through Kent County, joining the Grand River at Comstock Park. Three major tributaries enter the creek (Figure 1). Upstream, the land is rolling with orchards and grain predominating. Proceeding downstream the creek goes from agricultural to urban development. In general the stream may be described as a cold water, usually clear creek with a drainage system representative of a midwestern agricultural and urban creek of moderate size and low relief gradient.

Initially, sampling of pesticides, sediments, and nutrients were conducted at nine stations established from Cranberry Lake to the creek's mouth as it enters the Grand River. Comprehensive analyses of some 57 pesticide parameters allowed the identification of problem pesticides and then concentration of efforts on the transport processes responsible for movement of these problem pesticides within and from the creek. After the

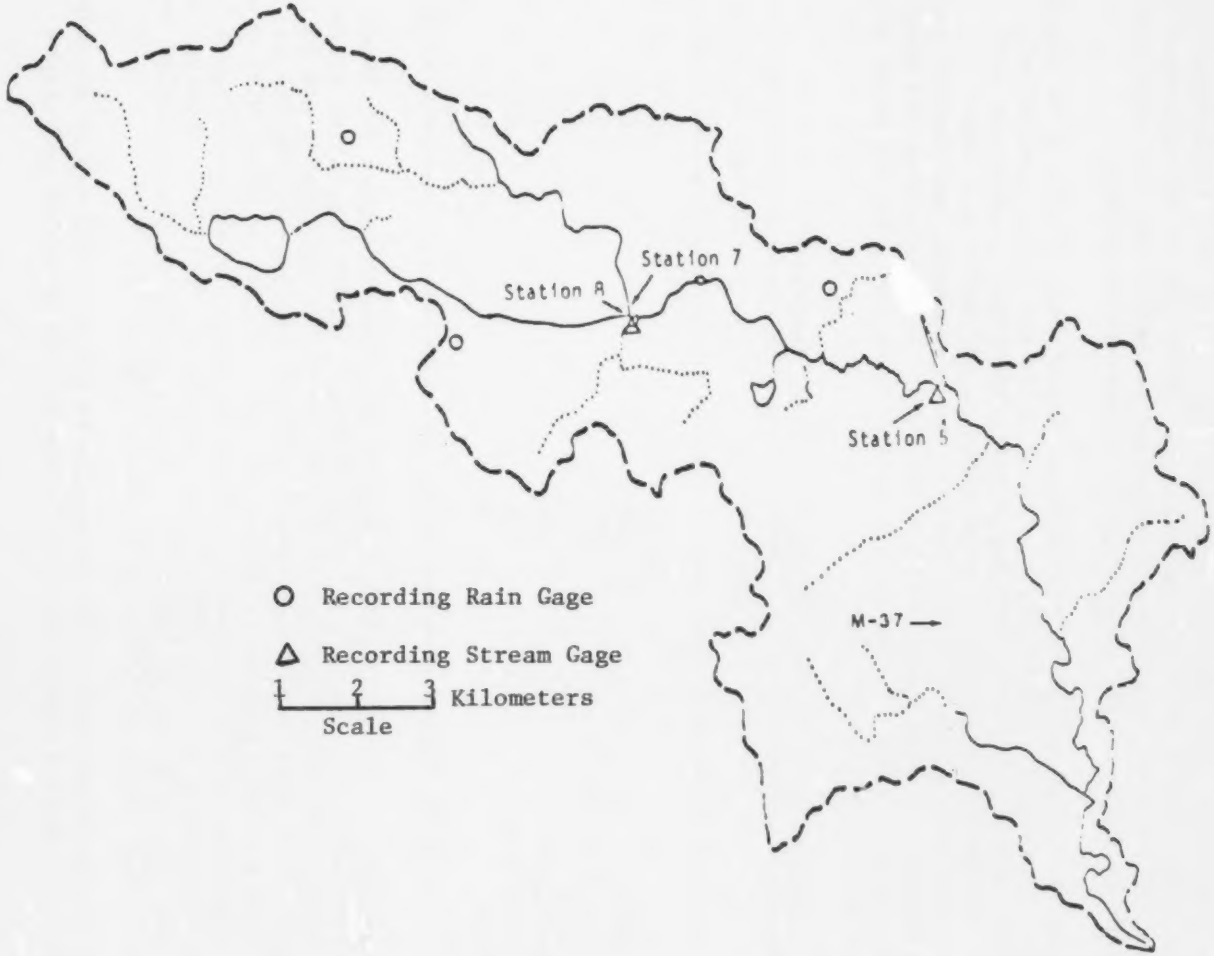

Station 7
Station 8
Station 5
M-37
○ Recording Rain Gage
△ Recording Stream Gage
1 2 3 Kilometers
Scale

Figure 1. Mill Creek Watershed

initial survey of the entire watershed, studies were concentrated on the agricultural portion of the watershed upstream of station 5 at M-37 (Figure 1). Downstream of M-37, the watershed becomes urbanized with housing subdivision, light industry, and a golf course -- land uses not indicative of the problem under investigation.

Land use in the 3058 ha watershed upstream of station 5 (Figure 1) is almost completely agricultural with about 90% of the area in cultivation and the other 10% in woodlots or wetlands. About 50% of the watershed is in corn, 30% in fruit orchards predominated by apples but with some cherries and other furits, and the remaining 10% in pasture or alfalfa.

Almost 90% of the soils are loams or loamy snads (Table 1) of glacial origin. In general, the higher elevation soils are almost exclusively loam with Nester, Marlette, and Capac being the three predominant soil types. In the areas adjacent to the streams, the soils are almost all loamy sands predominately of the Spinks, Brady, Oshtemo, and Chelsea series interspersed with pockets of muck, sandy loam, fine sandy loam and other alluvial lands (Table 1). Slopes are generally in the 2 to 12% range with some ridges in the 12-18% range.

Table 1. Major Soils of the 3058 ha Mill Creek Watershed

Soil	Area (ha)	Percent of Total
Loam	2,242	73.3
Loamy Sand	489	16.0
Muck	153	5.0
Sandy Loam	99	3.2
Alluvial Land	30	1.0
Fine Sandy Loam	6	0.2
Fine Sand	4	0.1
(Lakes)	35	1.1

Locations of major sampling stations are shown in Figure 1. There were three subwatersheds sampled with automatic (ISCO) sequential stormwater samplers so that loadings of major pesticides, sediments, and nutrients could be calculated. These three stations include (1) the 889 ha North Branch water (station 7, Figure 1), (2) the 1146 ha upper Mill Creek watershed prior to its confluence with North Branch (station 8, Figure 1), and (3) the entire 3058 ha agricultural portion of Mill Creek upstream of the urban area (station 5, Figure 1). Precipitation on the watershed was monitored with three recording rain gauges (Figure 1).

A review of the data from the stream is given in EPA report EPA-905/9-78-002. A short summary is given in the following tables and graphs.

Table 2. Mass Flow of Pesticides from Mill Creek, Michigan, During Three Storm Events

Storm date	Mean discharge (m^3/day)	Adsorbed pesticide transported (Kg)			Dissolved pesticide transported (Kg)			Suspended solids transported (Kg)
		DDT	DDE	Atrazine	DDT	DDE	Atrazine	
5/06 - 5/07/76	1764	0.008	0.005	a	0.011	0.0008	0.022	10400
5/28 - 5/31/76	104	0.001	0.025	a	0.003	None	0.047	1050
6/30 - 7/02/76	65	0.0004	0.00004	a	0.003	None	0.012	600

a Data not yet available

Table 3. Stream Export of Materials by the 3058 ha Mill Creek Watershed Above M-37

	1975-76			1976-77		
	Weighted mean (mg/1)	Total load (kg/yr)	Unit area load (kg/ha/yr)	Weighted mean (mg/1)	Total load (kg/yr)	Unit area load (kg/ha/yr)
Nitrate-N	1.765	20573 ± 5546	6.729	3.656	11786 ± 3496	3.854
Nitrite-N	0.025	288 ± 285	0.094	0.010	31.24 ± 3.58	0.010
Ammonia-N	0.078	912 ± 1023	0.298	0.020	62.95 ± 27.72	0.021
Total Kjeldahl N	0.782	9116 ± 2295	2.981	1.117	3602 ± 1090	1.178
Molybdate Reactive P	0.076	882 ± 298	0.288	0.181	582 ± 250	0.190
Total P	0.153	1782 ± 1018	0.583	0.313	1008 ± 331	0.330
Chloride	11.778	137303 ± 23509	44.900	19.808	63863 ± 8334	20.884
Calcium	49.676	579095 ± 111673	189.371	51.314	165439 ± 56926	54.100
Sodium	5.482	63901 ± 8939	20.896	5.984	19293 ± 3644	6.309
Suspended Solids	11.590	135114 ± 137425	44.184	47.985	154709 ± 146989	50.592

Table 4. Stream Export of Materials by the 889 ha North Branch Subwatershed of Mill Creek

	1975-76			1976-77		
	Weighted mean (mg/l)	Total load (kg/yr)	Unit area load (kg/ha/yr)	Weighted mean (mg/l)	Total load (kg/yr)	Unit area load (kg/ha/yr)
Nitrate-N	1.191	3529 ± 1433	3.970	0.885	568 ± 66	0.639
Nitrite-N	0.038	113 ± 137	0.127	0.010	6.38 ± .11	0.007
Ammonia-N	0.073	215 ± 229	0.242	0.010	6.61 ± .34	0.007
Total Kjeldahl N	0.696	2063 ± 938	2.321	0.465	229 ± 52	0.336
Molybdate Reactive P	0.073	217 ± 99	0.244	0.050	32.1 ± 12.5	0.036
Total P	0.171	506 ± 335	0.569	0.054	34.5 ± 14.1	0.039
Chloride	13.585	40246 ± 13602	45.271	30.527	19602 ± 1169	22.049
Calcium	53.698	159078 ± 42395	178.940	a	a	a
Sodium	6.687	19811 ± 5105	22.285	a	a	a
Suspended Solids	21.490	63655 ± 23995	71.614	a	a	a

a Insufficient data

Table 5. Stream Export of Materials by the 1146 ha Mill Creek Watershed Above the Confluence with North Branch

	1975-76			1976-77		
	Weighted mean (mg/l)	Total load (kg/yr)	Unit area load (kg/ha/yr)	Weighted mean (mg/l)	Total load (kg/yr)	Unit area load (kg/ha/yr)
Nitrate-N	1.511	5200 ± 2836	4.358	5.607	4061 ± 2316	3.544
Nitrite-N	0.013	44.2 ± 40.5	0.039	0.009	6.78 ± 1.74	0.006
Ammonia-N	0.100	344 ± 416	0.300	0.013	9.26 ± 12.10	0.008
Total Kjeldahl N	0.798	2745 ± 731	2.395	1.175	851 ± 301	0.743
Molybdate reactive P	0.063	216 ± 105	0.188	0.156	113 ± 43	0.099
Total P	0.139	478 ± 238	0.417	0.248	179 ± 109	0.156
Chloride	9.875	33986 ± 4377	29.656	19.265	13954 ± 2969	12.176
Calcium	42.438	146055 ± 25920	127.448	44.060	31913 ± 15662	27.847
Sodium	3.781	13012 ± 1605	11.354	3.807	2757 ± 1256	2.406
Suspended solids	16.388	56399 ± 35775	49.214	33.803	22484 ± 73338	21.365

Table 6. Pesticide Exports from the 3058 ha Mill Creek Water, 1975-76 Water Year[a]

	Event Flows				
Pesticide	Rising hydrograph (kg)	Descending hydrograph (kg)	Non-event flows (kg)	Total Exports (kg)	Unit area loads (kg/ha)
			Dissolved Pesticides		
DDT	0.500 ± .0002	15.427 ± .013	ND[b]	--	--
DDE	0.361 ± .0001	13.228 ± .012	ND	--	--
DDD	0.029 ± .00001	1.063 ± .001	ND	--	--
Aldrin	0.043 ± .00001	1.159 ± .001	ND	--	--
Dieldrin	0.083 ± .00003	2.669 ± .004	ND	--	--
Guthion	0.079 ± .00003	0.688 ± .002	ND	--	--
Atrazine	1.933 ± .0006	39.247 ± .124	ND	--	--
Simazine	0.174 ± .0001	2.898 ± .005	ND	--	--
			Filtered Pesticides		
DDT	4.859 ± .002	281.440 ± .09	13.859 ± 0.00	300.160 ± 0.09	0.0982
DDE	5.214 ± .003	196.550 ± .13	12.573 ± 0.00	214.340 ± 0.13	0.0701
DDD	0.474 ± .0002	17.420 ± .017	1.500 ± 0.00	19.394 ± 0.017	0.0063
Aldrin	0.526 ± .0002	1.570 ± .002	1.786 ± 0.00	3.882 ± 0.002	0.0013
Dieldrin	0.696 ± .0003	17.107 ± .024	3.429 ± 0.00	21.232 ± 0.024	0.0069
Guthion	0.451 ± .0002	6.612 ± .018	ND	--	--
Atrazine	13.807 ± .005	283.030 ± .85	ND	--	--
Simazine	3.307 ± .001	50.644 ± .172	ND	--	--

a There was 3.6 times more runoff in the 1975-76 Water Year than in the 1976-77 Water Year

b ND indicates no data

Table 7. Pesticide Exports from the 3058 ha Mill Creek Watershed, 1976-77 Water Year[a]

Pesticide	Event Flows Rising hydrograph (kg)	 Decending hydrograph (kg)	Non-event flows (kg)	Total Exports (kg)	Unit area loads (kg/ha)
DDT	1.852 ± .001	3.430 ± .036	0.433 ± 7.104	5.715 ± 7.104	0.00187
DDE	2.284 ± .002	3.411 ± .074	0.303 ± 1.245	5.998 ± 1.247	0.00196
DDD	0.097 ± .0001	0.178 ± .006	0.026 ± 0.000	0.301 ± 0.006	0.00010
Aldrin	0.113 ± .0001	0.156 ± .005	0.129 ± 0.553	0.398 ± 0.553	0.00013
Dieldrin	0.244 ± .0001	0.279 ± .014	0.047 ± 0.276	0.570 ± 0.276	0.00019
Guthion	0.007 ± .000004	0.026 ± .00002	0.031 ± 0.032	0.064 ± 0.232	0.00002
Atrazine	0.791 ± .001	1.230 ± .095	0.563 ± 12.865	2.584 ± 12.865	0.00084
Simazine	0.036 ± .00002	0.052 ± .004	0.144 ± 4.140	0.232 ± 4.140	0.00008
DDT	24.136 ± .020	58.413 ± 0.647	3.001 ± 5.201	85.550 ± 5.241	0.0280
DDE	33.261 ± .028	55.811 ± 1.261	2.732 ± 10.424	91.804 ± 10.580	0.0300
DDD	1.015 ± .001	2.888 ± 0.102	0.209 ± 1.674	4.112 ± 1.677	0.0013
Aldrin	0.945 ± .001	1.583 ± 0.067	0.182 ± 1.239	2.710 ± 1.241	0.0009
Dieldrin	1.912 ± .001	4.418 ± 0.235	0.377 ± 2.841	6.707 ± 2.851	0.0022
Guthion	0.151 ± .0001	0.697 ± 0.447	0.510 ± 2.600	1.358 ± 2.638	0.0004
Atrazine	7.152 ± .005	10.433 ± 0.675	5.537 ± 42.580	23.122 ± 42.585	0.0076
Simazine	0.706 ± .001	0.752 ± 0.061	1.486 ± 22.590	2.944 ± 22.590	0.0010

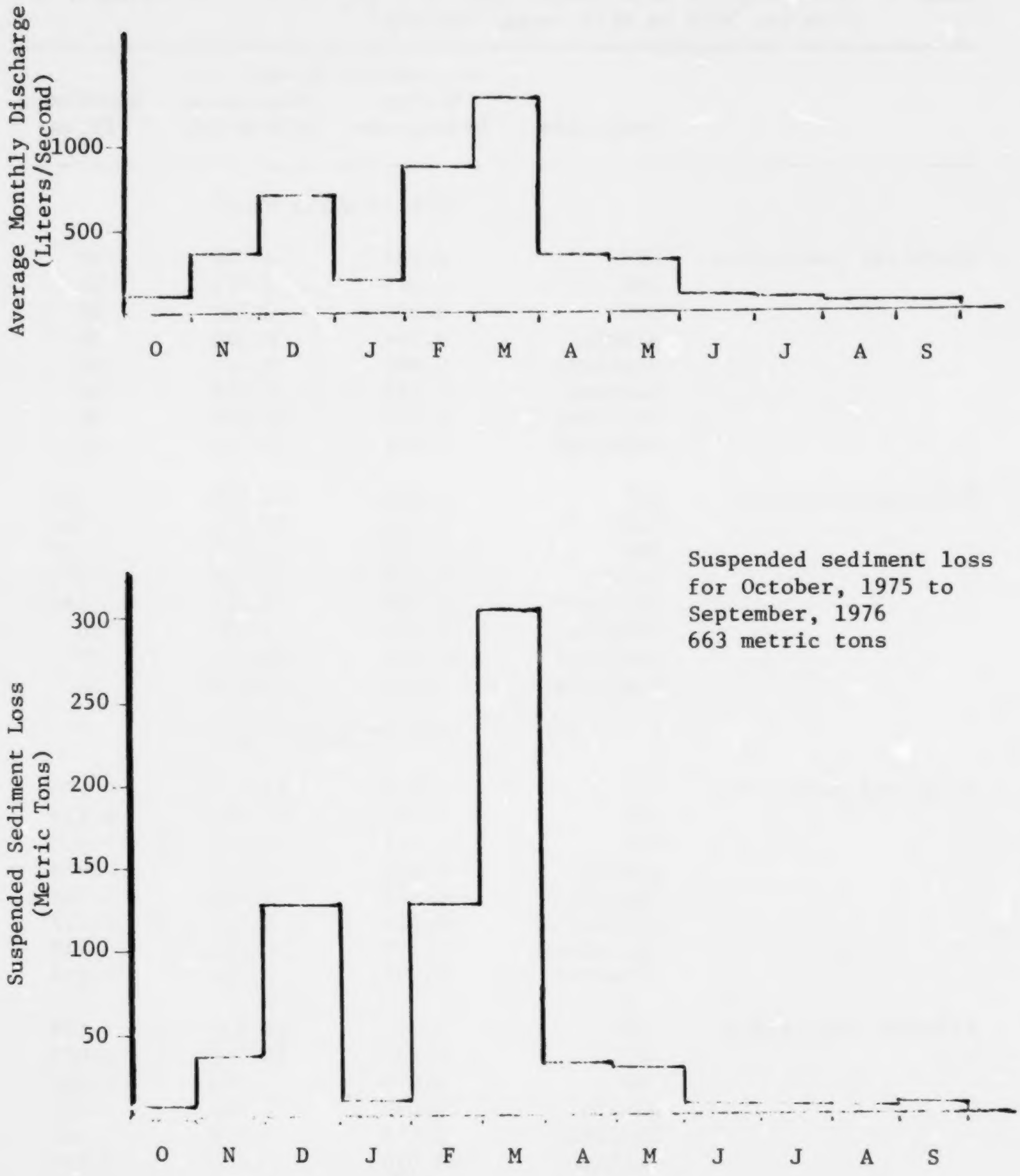
a There was 3.6 times more runoff in the 1975-76 Water Year than in the 1976-77 Water Year.

Table 8. Flow Weighted Mean Concentrations (μg/ℓ) of Pesticides Exported from the 3058 ha Mill Creek Watershed

		------Event Flows------		
	Pesticide	Rising hydrograph	Descending hydrograph	Non-Event flows
		1975-76 Water Year[a]		
Dissolved pesticides	DDT	0.531	4.166	ND[b]
	DDE	0.366	3.572	ND
	DDD	0.052	0.287	ND
	Aldrin	0.094	0.313	ND
	Dieldrin	0.097	0.721	ND
	Guthion	0.112	0.186	ND
	Atrizine	2.245	10.598	ND
	Simazine	0.201	0.782	ND
Filtered pesticides	DDT	5.192	75.998	1.940
	DDE	5.341	53.075	1.760
	DDD	0.799	4.704	0.210
	Aldrin	0.738	0.424	0.250
	Dieldrin	0.884	4.619	0.480
	Guthion	0.535	1.785	ND
	Atrizine	16.327	76.428	ND
	Simazine	3.828	13.676	ND
		1976-77 Water Year[a]		
Dissolved pesticides	DDT	1.201	13.727	0.170
	DDE	1.280	15.885	0.119
	DDD	0.045	0.640	0.010
	Aldrin	0.093	0.501	0.050
	Dieldrin	0.122	1.063	0.018
	Guthion	0.014	0.351	0.012
	Atrizine	1.198	6.862	0.221
	Simazine	0.071	0.725	0.056
Filtered pesticides	DDT	1.323	19.831	1.176
	DDE	1.232	18.769	1.071
	DDD	0.070	1.053	0.082
	Aldrin	0.083	0.585	0.072
	Dieldrin	0.113	[illegible].559	0.148
	Guthion	0.020	0.498	0.200
	Atrizine	0.753	5.624	2.170
	Simazine	0.027	0.408	0.582

[a] There was 3.6 times more runoff in the 1975-76 Water Year than in the 1976-77 Water Year

[b] ND indicates no data



Suspended sediment loss
for October, 1975 to
September, 1976
663 metric tons

Figure 2. Discharge and Suspended Sediment Loss from the Mill Creek, Michigan, Watershed

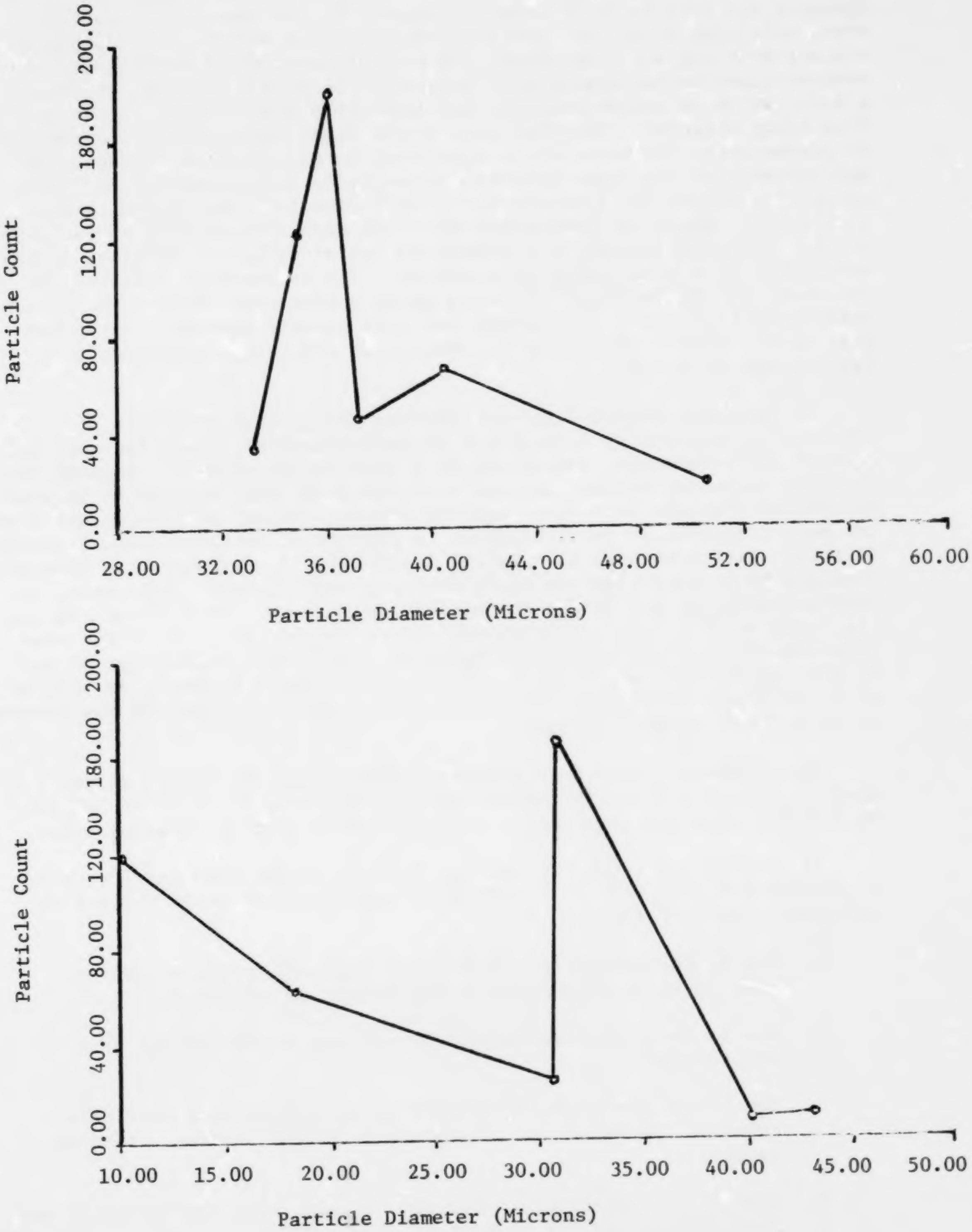


Figure 3. Particle size distribution of particles less than 100 microns in size transported during low flow periods on October 28, 1976 (flow = 110 /sec, upper figure) and on November 28, 1976 (flow = 189 /sec, lower figure). These size distributions were determined with a Coulter Counter, Model A.

The work presented in this portion is an effort to characterize the dynamics and effects of an example compound in the terrestrial environment, utilizing field and laboratory measurements and the methodology of systems modeling and simulation. Data collection, model refinement, and revised experimental design were done in an iterative fashion, yielding a model which is parameterizable and data which are relevant to the problem being attacked. Reported here is the field experimental program used to parameterize the model which describes the distribution, attenuation and movement of the organophosphate insecticide azinphosmethyl, 0,0-dimethyl-S-(4-oxo-1, 2, 3 benzotriazin-3(4H)-ylmethyl) phosphorodithioate (Guthion). While the laboratory and field work concentrated on the particular pesticide chosen, the techniques for studying and modeling it are applicable to a broad range of compounds. The compound is followed (in the model and in the field) from its spray application through the orchard soil/vegetation/litter environment and into aquatic systems. A further goal is to identify and model its impacts on non-target organisms in a terrestrial ecosystem.

To develop a methodology for modeling the ecosystem effects of alternative pesticides, a deciduous orchard ecosystem, among the most complex of agroecosystems, was chosen as a challenging example. In part due to their perennial nature, orchard ecosystems are more similar to natural ecosystems than are many other agroecosystems. Annual and semiannual crops are more transient in their behavior, a product of periodic radical changes in their environment due to cultural practices. In addition, the economic pressure to produce flawless fruit forces orchard growers to be among the heaviest users of pesticides in American agriculture. Ecosystems complextiy, coupled with high pesticide use, makes the orchard ecosystem a good indicator of possible ecological dangers. Additional hazards may be seen in sloping orchards where pesticides may be carried by runoff, as well as wind, to other terrestrial and aquatic environments, increasing the chances of potentially harmful pollution.

The organophosphate insecticide azinphosmethyl was chosen as the example pesticide to be introduced into the orchard, as it is one of the most widely used and potentially toxic compounds used in orchards today.

To develop, parameterize and test a model of the fate and impact of an alternative pesticide in an orchard ecosystem, four broad classes of information were desired:

1. How is the pesticide initially distributed in the ecosystem; what is its availability to the ecosystem population?

2. How is the pesticide redistributed; what forces affect this distribution?

3. How is the pesticide attenuated by its environment (microbial, chemical, photochemical degradation, volatilization, organism uptake)?

4. What is the relationship between the pesticide's attenuation and distribution and its effects on organisms?

It is obvious that the first three questions must be answered before the last; the model must represent the distribution, movement and attenuation of azinphosmethyl prior to its simulation of organism effects. The data base required for such a model is quite extensive. It amounts to a mass-balance of azinphosmethyl in the orchard (and leaving the orchard) with time. Available data from the literature merely gave initial direction to the field studies, as a consistent basis for formulating conclusions that could not be found among the various data reported.

Residue levels of azinphosmethyl with time on various plant surfaces, in the soil, and in the aquatic environment, were reported by the Chemagro Division Research Staff (1974). Liang and Lichtenstein (1972) examined the effects of light, temperature, and pH on the degradation of azinphosmethyl in water and on glass surfaces. In a later paper, (1976) they looked at photodecomposition of ^{14}C azinphosmethyl in soils and on leaf surfaces. Schulz et al. (1970) looked at the persistence and degradation of azinphosmethyl in soils as affected by formulation and mode of application. Yaron et al. (1974a) followed azinphosmethyl persistence and movement within the soil profile under irrigated field conditions. Iwata et al. (1975) looked at the behavior of azinphosmethyl is dust derived from several soil types. Heuer et al. (1974) studied the kinetics of azinphosmethyl degradation in aqueous solutions and on glass beads as affected by pH and temperature. Yaron (1974b) examined azinphosmethyl kinetics in the soil environment. Kuhr et al. (1974) examined the dissipation of azinphosmethyl from apple orchard soil when applied as a part of a routine spray program. Wieneke and Steffens (1974) compared the degradation of ^{14}C azinphosmethyl on glass paltes to the metabolism on bean leaves, and later studies (Steffens and Wieneke, 1975, 1976) further examined plant uptake and metabolism. Hall et al. (1975) and Hansen et al. (1978) followed the degradation of dislogeable azinphosmethyl residues on apple foilage. McMechan et al. (1972) measured the amount of azinphosmethyl erosion from apple leaves by rain and overtree irrigation. Thompson and Brooks (1976) looked at dislodgeable residues of azinphosmethyl and 4 other insecticides on citrus leaves and fruit during wet and dry weather in Florida. Gunther et al. (1977) discussed the dynamics of both penetrated and dislodgeable foliar residues on citrus, orchard soil dust residues, and airborne residues. Each of these papers supplies information on the dynamics of azinphosmethyl in one segment of the environment, be it soil, water, leaf surfaces, etc. To understand ecosystem effects, these processes must be considered part of the whole ecosystem and azinphosmethyl dynamics must be considered for every part at any point in time.

To overcome the gaps and inconsistencies in the literature, an abandoned apple orchard in the Mill Creek Watershed was converted into an experimental unit to gather data on the environmental dynamics of azinphosmethyl under a regime of periodic sprays. The orchard sampling was based on this whole-ecosystem principle using the literature as a source of expected values to determine initial sampling procedures.

The environmental behavior of pesticides was studied to develop a methodology for modeling ecosystems effects of alternative pesticides. Studies were carried out in an apple orchard watershed to gather data on both initial distribution of azinphosmethyl within the orchard and vertical movement of the pesticide under the influence of rainfall, as well as the attenuation of the pesticide in various situations. The orchard was subdivided into distinct plots. Each was further subdivided both vertically and horizontally in order to adequately represent the variations which affect the behavior and impact of the pesticide in the orchard ecosystem. Plots were designed such that each was a distinct watershed, allowing runoff collection from them individually. In addition, losses of azinphosmethyl to the atmosphere were examined, both during application and on subsequent days. In 1976 64.9% and in 1977 53.6% of the azinphosmethyl applied was initially distributed among the various orchard strata. Examination of residues reaching each stratum showed the majority of the dislodgeable residues are distributed to the trees and grass. Litter and soil residue levels are roughly 10 times lower than tree leaf residues. Runoff studies indicate a small contribution to the loss of azinphosmethyl from the orchard via this route. Analysis of residue data throughout the season indicates vertical pesticide movement among strata under both rainfall and no-rainfall conditions. Airborne residues collected at the downwind edge during spraying were roughly uniform to 6 meters and averaged 55.6 ± 6.9 μg/m^3. Levels measured 6 days after application averaged .27 ± .10 μg/m^3. The data presented here were used to parameterize a model for pesticide fate in a orchard ecosystem presented in Goodman et al. (1979). A model for organism effects parameterized using data from a companion study, conducted concurrently within the same orchard, is also described in Goodman, et al. (1979).

The results show that pesticides (chlorinated hydrocarbon pesticides in particular) are still a significant non-point source of contamination to Michigan rivers and consequently the bordering Great Lakes. The concentrations found are at the part per billion and trillion level but still are significant in terms of their effect on aquatic organisms due to biomagnification. The results of Mill Creek are supported by the fact that pesticides such as DDT and Dieldrin are found in Great Lake fish and are responsible for the ban on commercial fishing for Coho salmon, etc.

There does not appear to be any reasonable mechanism for the elimination of these pesticides from the river and streams short of what has already been implemented (ban on the use of chlorinated hydrocarbon pesticides). Prevention of sheet soil errosion would certainly be a measure that would reduce the amount of pesticides entering the Great Lakes but would certainly not stop the introduction of all pesticides due to evaporation, drift and other transport processes.

LIVESTOCK INPUTS AND EFFECTS
BY
FRED MADISON*

LIVESTOCK POLLUTION LOADS GOING INTO THE GREAT LAKES BECAME A MAJOR CONCERN OF CANADA AND THE UNITED STATES, THUS FROM THE INTERNATIONAL JOINT COMMISSION THROUGH PLUARG, PROGRAMS WERE SET UP TO INITIATE STUDIES TO ESTIMATE POLLUTION LOADS TO THE GREAT LAKES.

THE STUDIES COVERED THREE MAJOR SOURCE AREAS:

1. LAND APPLICATION SYSTEMS
2. BARNYARD FEEDLOT AREAS
3. WASTE STORAGE AREAS

AN EXTENSIVE LITERATURE SEARCH WAS UNDERTAKEN. THUS WE CONCLUDED PHOSPHORUS LOADINGS TO THE GREAT LAKES:

1. 5% OF THE PHOSPHORUS WAS TREATED ANNUALLY.
2. 10% SPREAD ON FROZEN GROUND FOR RUNOFF TO STREAMS.
3. 2% FROM EXCRETED SOURCES OF SOLIDS AND SEMISOLIDS.

DATA SET IN A SIMPLIFIED MODEL AND THESE CONCLUSIONS WERE DRAWN:

1. 1 TO 2.5% OF ALL MANURE PHOSPHORUS WAS DELIVERED TO THE LAKES.
2. 75% OF MANURE PHOSPHORUS FROM BARNYARDS WAS DELIVERED TO STREAMS.
3. 25% WAS FROM MANURE LAND APPLICATION SOURCES.

LOAD ESTIMATES FROM LAND MANAGEMENT PRACTICES APPLIED ON CROPLAND REVEALED:

1. 6 TO 15% REDUCTION IN PHOSPHORUS LOADINGS.
2. A 10% REDUCTION IN TOTAL PHOSPHORUS IN THE WATERSHED.

ANIMAL WASTE SOURCES ARE REDUCED:

1. 27 TO 36% REDUCTION IN ANIMAL WASTE PHOSPHORUS.
2. TOTAL WATERSHED PHOSPHORUS WAS REDUCED 9-13%.

---

*DR. FRED MADISON, DIRECTOR, WASHINGTON COUNTY NONPOINT SOURCE POLLUTION PROJECT. UNIVERSITY OF WISCONSIN SPEECH TAKEN FROM A RECORDING AND INTERPRETED BY CARL D. WILSON.

COSTS FOR CROPLAND TREATMENT:

1. 30,000 DOLLARS TOTAL COST FOR CROPLAND TREATMENT.

ANIMAL WASTE STORAGE FACILITIES ARE EXPENSIVE:

1. $15,000 TO $20,000 PER UNIT AND CAN RANGE TO $65,000.

ANIMAL WASTE SYSTEMS:

1. STORAGE AND APPLY TO LAND GOOD POLLUTION REDUCTION.
2. WATER QUALITY CONSTRAINTS THAT REQUIRE STORAGE IS THE EXCEPTION NOT THE RULE IN WISCONSIN.
3. RURAL LIVESTOCK SYSTEM WITH WATER DIVERSIONS CAN BE INSTALLED CHEAP $1500 TO $4000 FOUR YEARS AGO.

QUESTION?

1. ARE WE LOOKING AT THE WRONG PART OF THE PROBLEM?

OTHER STUDIES WERE SET UP IN WISCONSIN ON SIX BARNYARD SITES. THE SIZE OF THESE AREAS RANGED FROM 3 TO 5 ACRES.

1. DATA REVEALED LIVESTOCK IS A SIGNIFICANT SOURCE OF NUTRIENTS (POLLUTION LOADINGS).
2. WINTER APPLICATION OF MANURE:
   (A) REDUCES RUNOFF.
   (B) REDUCES NUTRIENT LOSSES.
   (C) EFFECT IS SPRING AND ALL THROUGH THE YEAR.

WHITE CLAY LAKE WATERSHED PROJECT SET UP IN WISCONSIN IN 1976. FIRST UPLAND TREATED WATERSHED PROGRAM. THE PROJECT WAS FUNDED BY THE CLEAN LAKES PROGRAM SECTION 314 FROM THE ENVIRONMENTAL PROTECTION AGENCY.

TWO MODELS DEVELOPED:

1. ANIMAL WASTE MODEL.
2. CROPLAND WASTE LOAD MODEL.

CONCLUDED:

1. 66% OF THE TOTAL PHOSPHORUS GETTING INTO THE LAKE CAME FROM CROPLAND.
2. 34% OF THE TOTAL PHOSPHORUS GETTING INTO THE LAKE CAME FROM ANIMAL WASTE.

UPSTREAM POINT SOURCE PHOSPHORUS INPUTS AND EFFECTS

by

David B. Baker*

One of the goals of water quality management is to obtain the greatest possible improvement in water quality and general environmental quality per dollar invested in pollution abatement programs. Although most water quality management plans include an economic analysis of alternative solutions to some particular problem, very often the examination of alternatives operates within a very narrow segment of the overall interacting set of causes and effects determining water quality. For example, a facility plan might include the selection of the most cost effective method of reducing the phosphorus concentrations in an effluent from 3 mg/l to 1 mg/l. If this reduction has no effect on water quality or if comparable expenditures on nonpoint controls or flow augmentation would have greater water quality benefits, then the examination of alternatives has operated within too narrow a framework of options. Certainly the objectives of this symposium and the concepts incorporated into the Watershed Model reflect the need to broaden the perspectives within which alternatives can be evaluated.

Although the concept of integrated point/nonpoint control programs is clear, the development and implementation of such programs is difficult because adequate data and necessary understanding is generally not available. In planning an integrated control program in the Great Lakes, the relationships outlined in the model illustrated in Figure 1 should be understood. The quality, quantity, timing and variability of inputs from both point and nonpoint sources into each area of the aquatic system should be known. Knowledge of the physical, chemical or biological processing of inputs within each area is important. This processing both affects and is affected by the water quality in the area. The processing also affects the movement of materials into either temporary or permanent storage within the system and the output of materials to the next area downstream. As the number of steps between a particular input and a water quality effect increases the more tenuous the cause and effect relationships become. This is certainly the case for the relationships between point source phosphorus inputs to stream systems and open lake water quality in Lake Erie.

Because of the complexities of the interacting systems illustrated in Figure 1, current efforts at integrated point/nonpoint control programs involve the use of a number of simplifying assumptions. Although the use of such assumptions does allow the development of integrated control programs, their use may undercut the effectiveness of the programs and prevent the realization of control economies that, given more information and better understanding, could be achieved.

The management of phosphorus within the Lake Erie Basin is one area in which opportunities for integrated point/nonpoint source management exist. Some of the major assumptions upon which such programs are based

---

*Director, Water Quality Laboratory, Heidelberg College, Tiffin, Ohio.

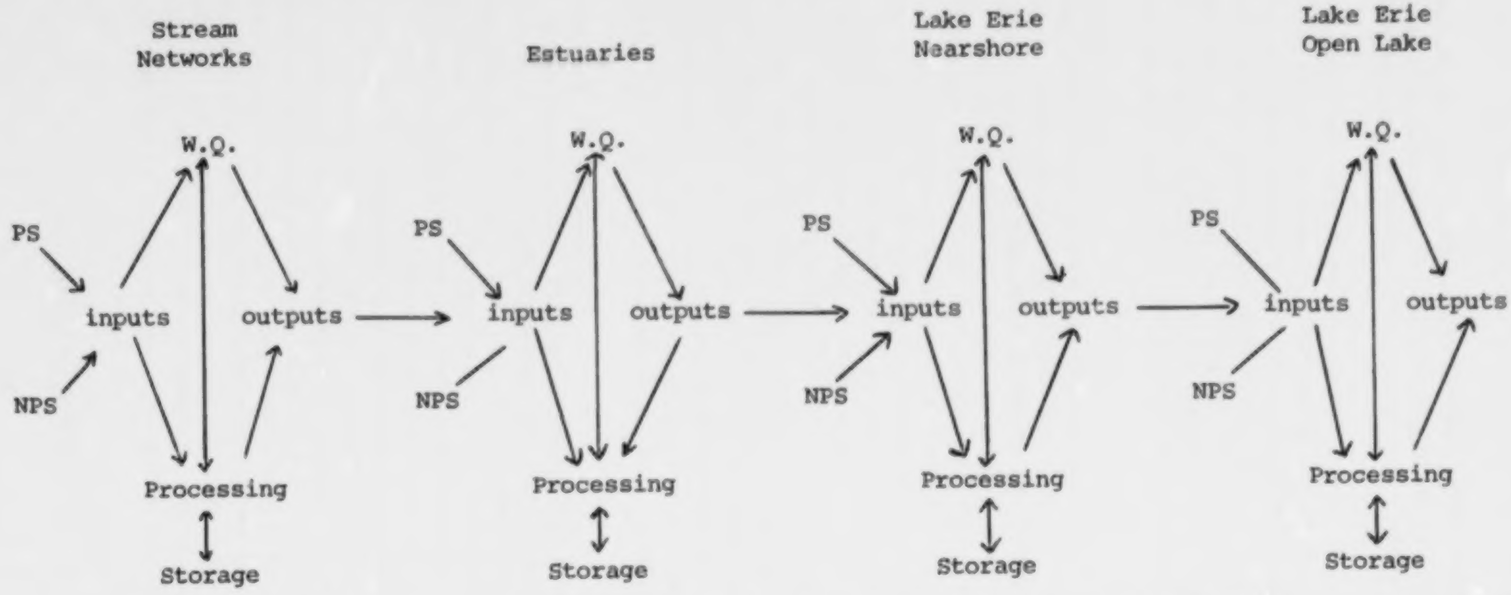

Stream Networks
Estuaries
Lake Erie Nearshore
Lake Erie Open Lake
W.Q.
PS
NPS
inputs
outputs
Processing
Storage

Figure 1. Areas requiring data and understanding to support the development of effective and economical integrated point source/nonpoint source control programs in the Lake Erie Basin. Abbreviations: PS, point sources; NPS, nonpoint sources; W.Q., water quality.

include:

1. Upstream (indirect) point source phosphorus inputs are assumed to have 100% delivery through the river to the lake unless large lakes or reservoirs are situated on the river system.

2. The bioavailability of upstream point source phosphorus is assumed to remain constant during transport to the lake.

3. Reductions in sediment and particulate phosphorus yields at river mouths are assumed to be proportional to the reduction in gross erosion achieved by the application of best management practices in the watershed.

4. No systematic differences in the processing of point source and nonpoint source-derived phosphorus within the estuaries and near shore zones of the lake are assumed to occur even though the mode of delivery of phosphorus derived from the two sources is very different.

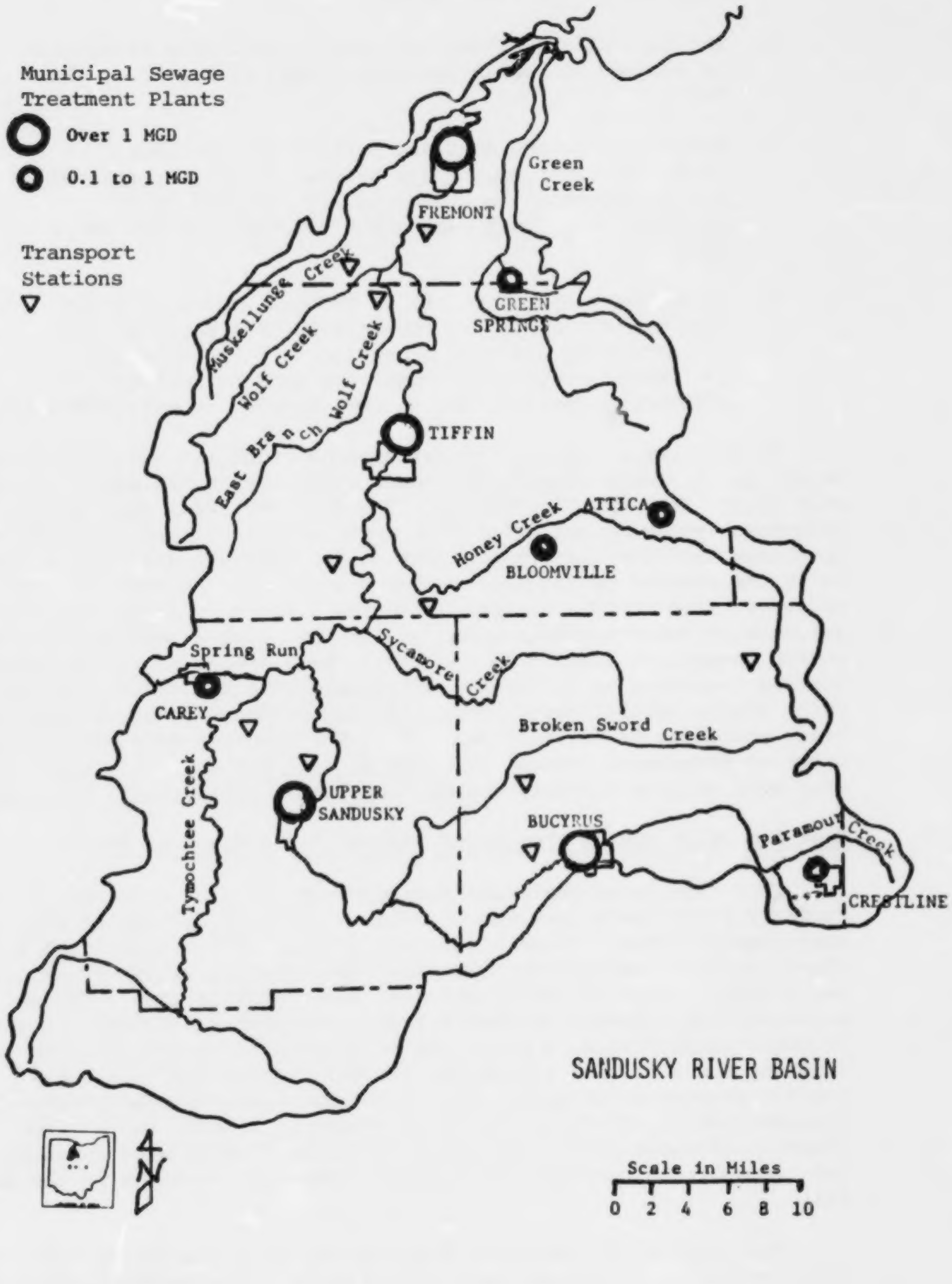
In this paper some of the assumptions regarding the effects of upstream point source phosphorus inputs will be examined using data available in the Sandusky River Basin. The data indicates that most of the phosphorus entering the river from upstream point sources becomes tied up within the river bottom sediments. Its eventual delivery to the lake is in the form of particulate rather than soluble phosphorus. The delivery ratio of this phosphorus to the lake is probably less than 100%. Evidence of ambient stream water quality problems associated with point source phosphorus loading is lacking. The nonpoint source phosphorus loading component is so large and variable that the effects of further point source control programs in reducing phosphorus output from the basin could not be directly measured. The transfer of funds from portions of phosphorus removal programs at upstream municipalities to alternate uses such as flow augmentation or nonpoint controls should be examined.

Upstream Point Source Phosphorus Inputs in the Sandusky Basin

There are seven municipal sewage treatment plants located in the Sandusky River Basin upstream from the Tindall Bridge gaging station near Fremont, Ohio. These plants are identified in Table 1 and their flows, effluent phosphorus concentrations, loading rates and annual loads are listed. Three of the plants have flows greater than 1 MGD and consequently are required to meet a 1 mg/1 phosphorus effluent standard. Of these three plants, Bucyrus has no phosphorus removal program; Upper Sandusky has a partial phosphorus removal program and Tiffin has a removal program which meets current requirements. No phosphorus removal programs are in effect at the other sewage treatment plants. The locations of these plants are shown in Figure 2 which also includes the locations of the nutrient and sediment transport stations in the Sandusky Basin.

The combined effluents of these plants load phosphorus into the river system at an average rate of 5.3 kg/hr. The annual loading from

Figure 2. Location of Municipal Sewage Treatment Plants and Sediment and Nutrient Transport Stations in the Sandusky River Basin


Municipal Sewage Treatment Plants
Over 1 MGD
0.1 to 1 MGD
Transport Stations
Green Creek
FREMONT
Muskellunge Creek
Wolf Creek
East Branch Wolf Creek
GREEN SPRINGS
TIFFIN
Honey Creek
ATTICA
BLOOMVILLE
Spring Run
Sycamore Creek
CAREY
Broken Sword Creek
Tymochtee Creek
UPPER SANDUSKY
BUCYRUS
Paramour Creek
CRESTLINE
SANDUSKY RIVER BASIN
N
Scale in Miles
0 2 4 6 8 10

the plants is about 45 metric tons per year. The mean annual export of total phosphorus at the Fremont gaging station is 355 metric tons per year (Baker, 1980). Assuming that all of the upstream municipally derived phosphorus is exported from the basin, point sources account for 13 percent of the total load and nonpoint sources 87 percent.

Table 1. Indirect Municipal Point Source Phosphorus Discharges in the Sandusky River Basin, 1978

Location	Flow 10^3 M^3/day	(MGD)	Total Phos. mg/l	Loading Rate Kg/hr.	Annual Load M Ton/yr.
Crestline	2.1	(.55)	6[a]	.52	4.6
Bucyrus	7.7	(1.9)	8.0	2.6	22
Upper Sandusky	6.4	(1.7)	2.5	.67	5.8
Cary	2.3	(.6)	6[a]	.57	5.0
Attica	.87	(.23)	6[a]	.22	1.9
Bloomville	1.1	(.28)	4[a]	.18	1.6
Tiffin	13.	(3.5)	0.9	.49	4.3
Total	33	(8.8)		5.3	45

[a] Estimated. Data from IJC 1979; De Pinto, et al, 1980, and Ohio EPA, 1979.

Instream Deposition of Phosphorus from Municipal Point Sources

The extent of deposition of municipally derived phosphorus in the Sandusky Basin can be studied through an analysis of both flux patterns and concentration patterns. Since the transport stations in the Sandusky Basin have been operated on a continuous basis for periods from 3 to 5 years, extensive data is available on phosphorus transport rates during both low and high flows. These data can be arranged in the form of flux exceedency tables. A summary of the phosphorus flux exceedency table for the Fremont gaging station is shown in Table 2.

The data in Table 2 are based on the analysis of 2,304 samples collected between December 26, 1973 and November 30, 1979. These samples were used to characterize the stream transport for a total period of 32,635 hours (3.73 years) with individual sample characterizing transport for periods ranging from 3 to 24 hours. During this time a total of 2,097 metric tons of total phosphorus and 393 metric tons of soluble reactive phosphorus were exported past the station. A computer program is used to rank all of the samples on the basis of instantaneous flux from the lowest to the highest value. The program lists the individual flux, the percent of the total period of time the fluxes were equal to or less than the listed value and the percent of the total flux accounted for by the listed value and all smaller flux rates. For example, 70% of the time the flux rate of total phosphorus was 16.5 kg/hr. or less and during that time 4.0% of the total observed total phosphorus flux had been exported.

The weighted average stream flow during the period of observation was 39 m^3/sec. This compares with a long term average discharge at the

Fremont station of 27 m^3/sec. Thus the data set is biased toward high flows.

Table 2. Characteristics of Phosphorus Export from the Sandusky River Basin, Tindall Bridge, Fremont, Ohio, 1974-1979

Time Weighted Percentile (instantaneous Flux)	Total Phosphorus		Soluble Reactive Phosphorus	
	Flux Rate Kg/hr.	Cum. % of Annual Load	Flux Rate Kg/hr.	Cum. % of Annual Load
10	.74	.08	.16	.07
20	1.33	.24	.37	.27
30	2.08	.50	.70	.70
40	3.06	.89	1.13	1.4
50	4.32	1.5	1.89	2.6
60	7.03	2.3	3.06	4.6
70	16.5	4.0	5.44	7.9
80	41.3	8.2	11.7	14.
90	137	20.	33.6	32
95	339	37	61.2	49
98	776	61	112	69
100	2610	100	587	100

From Table 2 it is apparent that the combined export of phosphorus from all sources is less than the point source inputs for more than 50% of the time. Fifty percent of the time the flux rate of total phosphorus at the Fremont station was less than 4.32 kg/hr.

It should also be noted that when the flux rate is 4.32 kg/hr. only about one third of that phosphorus could have come from point source inputs. Since the flux increases with stream discharge, the median flux should correspond to the median stream discharge. At the Fremont stream gage the median discharge rate is 563 X 10^3 M^3/day. The combined flow of the upstream municipal sewage treatment plants is 33 X 10^3 M^3/day. Therefore, 530 X 10^3 M^3/day or 94% of the median stream flow, is derived from various components of the basin hydrological cycle. In Sandusky subbasins lacking point source phosphorus inputs (Tymochtee Creek, Broken Sword and Wolf, East), the average phosphorus concentration at the median flow is 0.13 to 0.14 mg/l. Assuming that these are the background concentration characteristics of the Sandusky Basin at median stream flows, the background phosphorus flux at the Fremont gage would be 2.9 kg/hr. Consequently, of the 4.3 kg/hr. median flux, only 1.4 kg/hr. could be derived from point source inputs. This is about 25% of the point source input rate of 5.3 kg/hr. These calculations are summarized in Table 3.

The data presented in Table 2 also show that only 1.5% of the total observed load had been exported by the cumulative fluxes lower than the median flux. Applying this figure to the average annual export of phosphorus at the Fremont gage, suggests that only 5.3 metric tons of phosphorus would have been exported during the 50% of the time with the lowest fluxes. Since the loading rate from municipal sources is rather constant, one half of the annual point source inputs of phosphorus

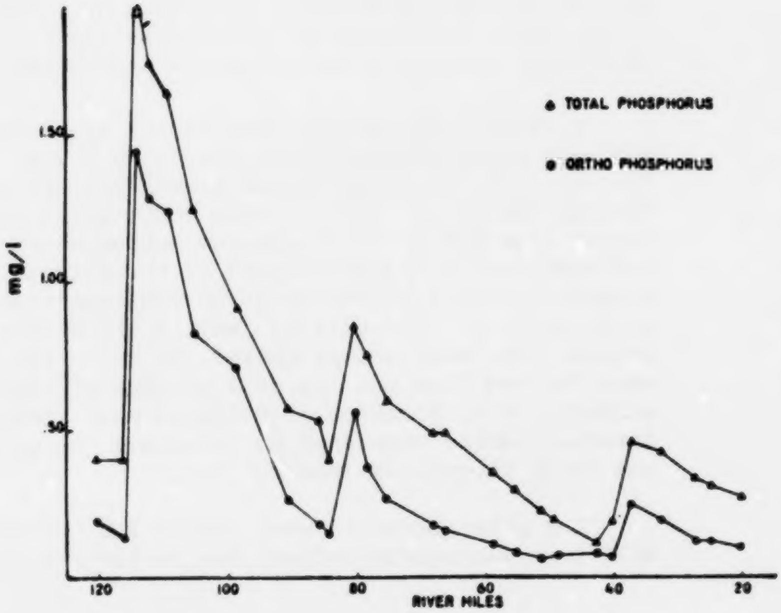
(22.5 metric tons) would have entered the river during this time. Thus during this time the combined point and nonpoint phosphorus export is only 24% of the point source phosphorus inputs. Since much of the phosphorus export during this time is derived from nonpoint sources, it is evident that the bulk of the point source phosphorus inputs is being incorporated into the stream sediments.

Table 3. Components of the Median Phosphorus Flux at Tindall Bridge in Fremont

Median Stream Discharge	563 x 10^3 M^3/day
Combined STP Discharges	-33 x 10^3 M^3/day
Background Stream Flow	530 x 10^3 M^3/day
Background Phosphorus Conc.	0.133 mg/l
Background Phosphorus Flux	2.9 Kg/hr.
Median Phosphorus Flux	4.3 Kg/hr.
Point Source Component of Flux	1.4 Kg/hr.
Point Source Input Rate	5.3 Kg/hr.

The occurrence of instream deposition of phosphorus from municipal point sources is also apparent from studies of the patterns of phosphorus concentration along the river. During the summer of 1974, from 32 to 52 samples were collected during nonstorm conditions at each of twenty six stations along the mainstream of the Sandusky River. The mean concentrations of total and soluble reactive phosphorus are shown as a function of mile point (distance from the river mouth) in Figure 3. The effects of inputs from the Bucyrus, Upper Sandusky and Tiffin sewage treatment plants are evident. None of the plants had phosphorus removal programs in operation at that time. The decreases in phosphorus concentration below each town reflect deposition of phosphorus rather than dilution effects. These data have been presented and discussed in the Proceedings of the Sandusky River Basin Symposium (Baker and Kramer, 1975).

Figure 3. Profiles of mean concentrations of phosphorus along the river system during June through September, 1974. Mileages shown are the distances from the mouth of the river. The three peaks in phosphorus concentration are caused by the effluents of the Bucyrus, Upper Sandusky and Tiffin sewage treatment plants.



Export of Upstream Point Source Phosphorus Inputs

Transmission Coefficients: Although it is evident from the above discussion that much of the upstream point source phosphorus input is incorporated into the river sediments, it is generally assumed that this phosphorus is resuspended during high flow periods and subsequently transported as available phosphorus to Lake Erie (Sonzogni, et al, 1980). Considerable evidence has been accumulated which documents the significance of deposition-resuspension phenomena in the transport of both sediments and phosphorus through river systems (Verhoff, et al, 1978; U.S. Army Corps of Engineers, 1979). Although mass balances for individual storms moving through the Sandusky Basin have been conducted (Melfi & Verhoff, 1979) the results do not provide information on the transmission coefficient of point source-derived phosphorus through the stream system on an annual basis.

One approach to determining the transmission coefficient from upstream point source inputs would be to achieve a known reduction in phosphorus inputs from these sources and compare this with an accompanying reduction in total river export of phosphorus. This approach does not work well where point source inputs are small relative to nonpoint inputs and where nonpoint inputs are extremely variable from year to year. From a study in 1972 (Baker and Kramer, 1973) the mean annual export of total phosphorus from the Sandusky Basin was estimated to be 445 metric tons. This estimate was based on a weighted mean concentration from 160 samples collected during both high and low flows and the mean annual flow for the period of record. Since that time, phosphorus removal programs have resulted in a decrease in phosphorus loading from point sources of about 40 metric tons per year. During the period from 1975 to 1979, the annual phosphorus export averaged 420 metric tons per year and ranged from 257.5 to 563.4 metric tons (Table 4). The average deviation from the mean during this time was 74 metric tons. Should Bucyrus and Upper Sandusky meet the 1 mg/l effluent standard, an additional reduction in phosphorus inputs from point sources of 23 metric tons per year would be achieved. The total reduction program of 63 metric tons per year would still be less than the average deviation in annual loading observed during the past 5 years. Thus determining transmission coefficients of point source phosphorus by comparing known reductions of phosphorus inputs with observed reductions in phosphorus outputs is not feasible within the Sandusky Basin.

A second approach to determining transmission coefficients is to evaluate phosphorus/sediment ratios in basins with and without point sources. If all of the point source-derived phosphorus is delivered through the stream system, then subtracting the point source phosphorus inputs from the total phosphorus output should give nonpoint phosphorus/sediment ratios characteristic of strictly agricultural watersheds. This assumes that all of the observed sediment transport is derived from nonpoint sources. The data in Table 5 illustrates the application of this method. The mean annual yields, to which the method has been applied, were derived from the use of a minimum of three years of record at each station. A combination of weighted mean concentrations and long term flow duration tables were used to calculate the mean annual yields of sediments and total phosphorus (Baker, 1980).

The phosphorus/sediment ratios for the Broken Sword, Tymochtee and Wolf East watersheds reflect the ratios for agricultural watersheds lacking source inputs. In the case of Bucyrus, the phosphorus sediment ratio (3.42) is much higher than the adjacent agricultural watershed (Broken Sword). Assuming 100% transmission of upstream point source inputs, these inputs are subtracted from the total phosphorus yield to give a nonpoint phosphorus yield. The resulting nonpoint phosphorus/sediment ratio (1.28) is much lower than the adjacent agricultural watershed. It should be noted that agricultural land use dominates all of these watersheds including those with point source inputs. The low calculated ratio suggests that not all of the point source inputs are resuspended and exported from the stream system.

Table 4. Annual variability in sediment and nutrient loading from the Sandusky River near Fremont, Ohio

Water Year	Discharge 10^9 M^3	Susp. Solids M. tons (mg/l)	Total Phosphorus M. tons (mg/l)	Sol. Reac. Phosphorus M. tons (mg/l)	Nitrate Nitrogen M. tons (mg/l)
1975	1.030	302,200	418.9	72.42	4709.
		293	.406	.070	4.57
1976	.772	124,000	398.9	49.67	2621
		161	.517	.064	3.39
1977	.629	98,800	257.5	65.76	3135
		157	.409	.104	4.98
1978	1.391	193,500	463.4	116.90	4958
		139	.333	.084	3.56
1979	1.087	285,500	563.4	112.2	5615
		262	.518	.103	5.16

Table 5. Use of Phosphorus/Sediment Ratios to Analyze Delivery of Upstream Point Source Phosphorus Inputs

Location	Component	Mean Annual Sediment Yield M.T./yr.	Mean Annual Phosphorus Yield M.T./yr.	TP/SS g/kg
Bucyrus	Total	12,400	42.5	3.42
	Point Source		-26.6	
	"Nonpoint Source"		15.9	1.28
Upper Sandusky	Total	48,600	111.9	2.30
	Point Source		-32.5	
	"Nonpoint Source		79.4	1.63
Broken Sword		18,900	31.0	1.64
Tymochtee		30,800	62.8	2.04
Wolf, East		12,900	29.8	2.31

The application of this method at Upper Sandusky gives less clear-cut results. The calculated nonpoint phosphorus/sediment ratio of 1.63 is lower than two of the agricultural watersheds but is about the same as the ratio in the Broken Sword Watershed. The relatively low ratios of point to nonpoint source phosphorus in these watersheds makes this approach to determining point source transmission characteristics difficult.

A third approach to evaluating the transmission of upstream point source phosphorus through the stream system would be to analyze the delivery of sediment through the system. One of the probable temporary sinks of phosphorus in the stream systems is through adsorption to sediments. Some fraction of these sediments will be deposited on flood plains during the large floods which account for much of the sediment and phosphorus yields. Point source-derived phosphorus which becomes adsorded to these sediments could, therefore, be deposited on flood plains. The accumulation of materials on flood plains represents permanent sinks for sediment and phosphorus relative to the time-frames of water quality management planning. According to soil surveys in the Sandusky Basin, there are a number of flood plains upon which sediments are accumulating (Steiger, 1975). Quantification of this accumulation is lacking and consequently the extent of transmission losses of sediment and particulate phosphorus through deposition on flood plains cannot be readily estimated. Impoundments along streams and rivers could also provide permanent sinks for point source-derived phosphorus that is adsorbed on sediment particles.

Although it is probable that the transmission of point source-derived phosphorus through the stream system is less than 100%, quantitative determinations of transmissions coefficient in large agricultural river basins is very difficult to attain.

Bioavailability: The instream deposition of phosphorus from upstream point sources could involve biological uptake by periphyton or rooted aquatic plants, adsorption to sediment particles or some type of chemical precipitation reaction. Storm routing methods which show resuspension of total phosphorus do not show release of soluble reactive phosphorus back into the water column (Melfi, et al. 1979). That portion of the deposited phosphorus that is delivered to Lake Erie apparently arrives as particulate phosphorus. It is probable that during its period of storage in the stream bed, at least some of the point source-derived phosphorus is converted to unavailable or slowly available particulate phosphorus. Part of it could be converted into refractory forms by biological processes while part could undergo chemical transformations. Once in the lake particulate phosphorus, whether bioavailable or not, is subject to removal from the water column through sedimentation. This particulate phosphorus is less available than soluble reactive phosphorus derived from nonpoint sources and delivered to the lake during storms or soluble reactive phosphorus delivered to the lake by direct point sources.

By far the highest loading rates of soluble reactive phosphorus to the lake occur during storm events. In the Sandusky Basin 50% of the annual export of soluble reactive phosphorus occurs during the 5% of the time with the highest fluxes. At these times, the orthophosphorus loading rates exceeded 61.2 kg/hr. These rates dwarf not only the upstream point source inputs, but also the direct point sources in the basin, including Fremont at 0.85 kg/hr. and Sandusky at 1.5 kg/hr. (IJC, 1979). The higher flow velocities during these storm events probably result in a high delivery of this nonpoint-derived soluble reactive phosphorus through the esturine and nearshore processing zones to the open lake system. It is possible that during non-storm conditions, soluble reactive phosphorus from direct municipal discharges is processed and deposited in the esturaries and nearshore zones in a fashion similar to the deposition of upstream point source phosphorus. Nearshore processing of phosphorus has been reported by Richards(1979). If esturine and nearshore processing of direct point sources to the lake is extensive, then a mass balance of soluble reactive phosphorus to the open lake water could be dominated by soluble reactive phosphorus derived from nonpoint sources and delivered to the lake during storm events.

Since upstream point source-derived phosphorus is in a particulate form when it reaches the lake, it will be less available than phosphorus entering the lake from direct point sources. Soluble reactive phosphorus derived from nonpoint sources could be an extremely important component of the bioavailable phosphorus reaching the open lake system.

Ambient Stream Water Quality Effects

One effect of upstream point source phosphorus control programs is to lower the phosphorus concentration in the stream system, especially in the zones immediately downstream from outfalls. The effect of point source loading on stream phosphorus levels is greatest during periods of low stream flow. As stream flows increase, the increasing dilution of the point source effluents decreases the impact of the effluent on stream concentrations. Water quality problems could be associated with the elevalted phosphorus concentrations if they result in increased growth of rooted aquatic plants, periphyton or phytoplankton. If these growths reach nuisance levels and cause excessive diurnal oxygen fluctuations, then ambient stream water quality problems could be attributed to the point source phosphorus inputs.

In the Sandusky Basin rooted aquatic plants are uncommon. Phytoplankton chlorophyll levels along the river were not decreased by the implementation of phosphorus removal programs along the river (unpublished data, Heidelberg Water Quality Laboratory). Nuisance growth of algae do develop along the river but these seem to be more related to periods of low stream flow and stream gradients than to phosphorus levels. Much of the time turbidity associated with the transport of fine clay probably limits growth of plant communities. It does not appear that the elevated phosphorus concentrations from point sources, where and when they occur in the Sandusky Basin, cause significant water quality problems.

There is a lack of information on the effects of nutrients on plant growth in stream systems. Responses probably vary considerably from stream to stream as well as with position in the stream system (Cummins, 1975). The need for additional studies on this topic for streams in southern Ontario has been recently cited (Wong, et al. 1979). In the river quality assessment program conducted for the Williamette River Basin in Oregon, it was concluded that flow augmentation was a more effective and economical procedure for controlling algae than advanced waste treatment. (Rickert, et al., 1977).

Discussion

Although the data available in the Sandusky Basin does not currently provide quantitative values on the transmission coefficient of upstream point source phosphorus to Lake Erie or its bioavailability upon reaching the lake, it is clear that its form and mode of delivery to the lake is quite different than for direct point sources. The bulk of the upstream point source-derived phosphorus that does reach the lake will be delivered during storm events at which time it is a small part of the total particulate phosphorus load. The nonpoint component of the particulate phosphorus load is so variable that reductions in point source loads cannot be readily detected.

Because of in-stream processing of upstream point source phosphorus, the impacts of this phosphorus on lake water quality are likely to be quite different than for direct discharges to the lake. Consequently, different requirements for phosphorus removal should be considered for upstream point sources. This could include careful analyses of the costs for varying degrees of phosphorus removal at these plants. Consideration of the water quality benefits that could be achieved through diverting portions of funds needed to operate phosphorus removal programs to supporting nonpoint source implementation programs or flow augmentation programs should be considered.

Table 6. Summary of Municipal Point Source Phosphorus Loading to the Great Lakes, 1978[a]

Basin	Direct Kg/day	Indirect Kg/day	Total Kg/day
Superior	351	291	641
Michigan	1,353	2,249	3,602
Huron	463	693	1,156
Erie	12,165	3,860	16,025
Ontario	5,240	1,644	6,884
Total	19,572 (69%)	8,737 (31%)	28,308
Detroit	7,178		
	12,394 (59%)	8,737 (41%)	

[a] Source IJC, July, 1979.

Within the Great Lakes System, indirect point sources account for a considerable portion of the total point source phosphorus inputs (Table 6). More information is needed on the open lake impacts of phosphorus derived from upstream point sources in comparison with the impacts of soluble reactive phosphorus delivered during storm events. Lacking this information, the effectiveness of alternative control programs for the lakes cannot be accurately predicted.

REFERENCES

Baker, David B., 1980. Final Report on EPA Grant No. R805436-01-1 in preparation.

Baker, David B. & Kramer, Jack W., 1973. Phosphorus Sources and Transport in an Agricultural River Basin of Lake Erie. Proc. 16th Conf. Great Lakes Res., p. 858-871.

Baker, David B. & Kramer, Jack W., 1975. Distribution of Non-Point Sources of Phosphorus and Sediments in the Sandusky River Basin. Proc. Sandusky River Basin Symposium, IJC, p. 61-88.

Cummins, Kenneth W., 1975. The Ecology of Running Waters, Theory and Practice. Proc. Sandusky River Basin Symposium, IJC, p. 277-294.

IJC, 1979. Inventory of Major Municipalities and Industrial Point Source Dischargers in the Great Lakes Basin. Great Lakes Water Quality Board.

DePinto, Joseph V., et al., 1980. Phosphorus Removal in Lower Great Lakes Municipal Treatment Plants. Municipal Env. Res. Lab., U.S. EPA, Cincinnati, 147 p.

Melfi, David A., et al., 1979. "Material Transport in River Systems During Storm Events by Water Routing," LEWMS Technical Report. U.S. Army Corps of Engineers, Buffalo, NY, March, 1979.

Ohio EPA, 1979. Initial Water Quality Management Plan, Sandusky River Basin, Prt. I, II, III.

Richards, R. Peter, 1979. Limnological Surveillance of the Nearshore Zone of Lake Erie in Central and Eastern Ohio. Pt. I: Chemical Limnology. Prepared for U.S. EPA, Region V.

Rickert, David A., et al., 1977. Algal Conditions and the Potential for Future Algal Problems in the Williamette River, Oregon. Geo. Survey Circular 715-G.

Sonzogni, William C., et al., 1980. Watershed: A Management Technique for Choosing Among Point and Nonpoint Control Strategies. U.S. EPA Region V Seminar on Water Quality Management Trade-Offs.

Steiger, Joseph R., 1975. Soil Surveys as a Tool in Studies on Nonpoint Sources of Stream Sediment. Proc. Sandusky River Basin Symposium, IJC, p. 89-96.

U.S. Army Corp of Engineers. 1979. Lake Erie Wastewater Management Study Methodology Report. U.S. Army Corps of Engineers, Buffalo, NY. 146 p.

Verhoff, Frank H., et al., 1978. Phosphorus Transport in Rivers. U.S. Army Corps of Engineers, Buffalo, NY.

Wong, S. L., et al., 1979. An examination of the Effects of Nutrients on the Water Quality of Shallow Rivers. Hydrobiologia, vol. 63, 3, p. 231-239.

SEDIMENT AND PHOSPHORUS TRANSPORT

BY

STEPHEN M. YAKSICH*

DAVID A. MELFI*

JOHN R. ADAMS*

September 1980

*Lake Erie Wastewater Management Study
U. S. Army Corps of Engineers
Buffalo District

SEDIMENT AND PHOSPHORUS TRANSPORT

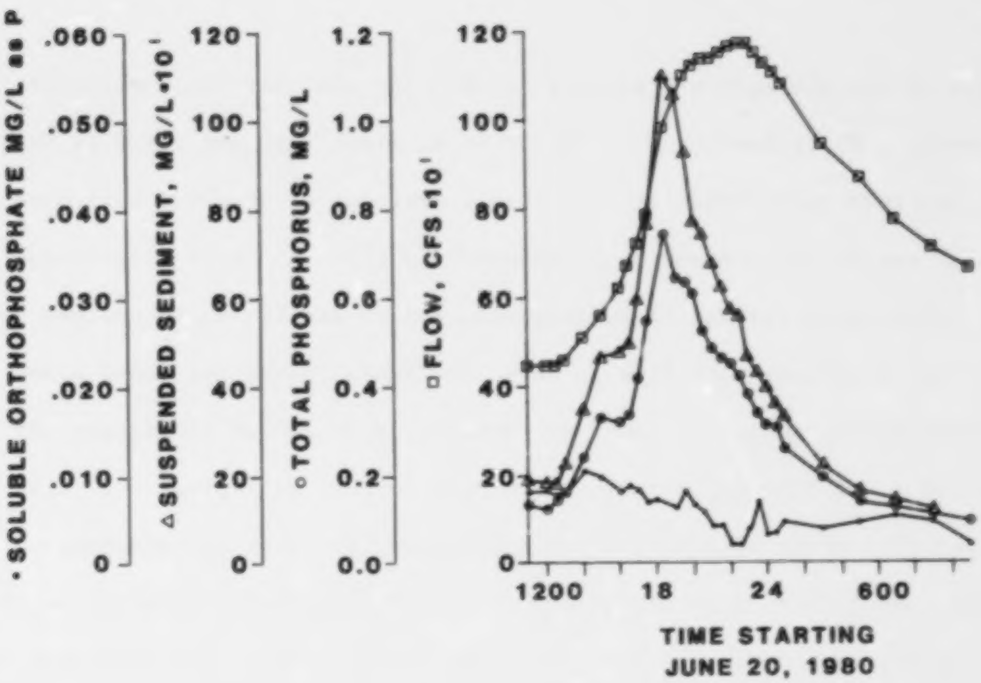
INTRODUCTION

The characteristics of sediment and phosphorus transport in a particular river affect how a river should be monitored and the type of information which can be obtained. Transport characteristics vary between rivers and sections of rivers, as well as hourly, daily, seasonally, and annually. Different types of monitoring programs are needed to measure ambient water quality and annual loads. Changes in annual loads do not necessarily reflect changes in the watershed conditions brought about by water quality management programs. This paper discusses river transport characteristics which are observed and how they can be used to understand transport mechanisms. It compares sampling programs required to measure annual loads and examines variations in annual loads and their effect on success monitoring. It points out problems with using unit area loads and loading functions to estimate phosphorus and sediment loads. Finally, it presents a monitoring program to make reliable annual load estimates and a program for success monitoring.

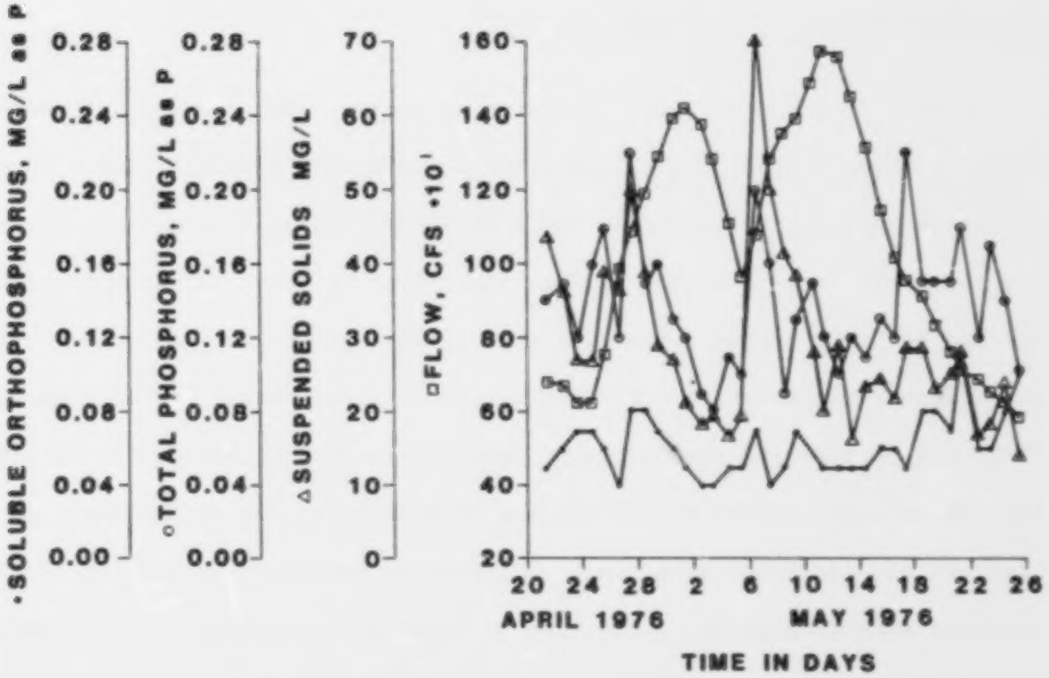
OBSERVATIONS OF TRANSPORT

CHEMOGRAPH OF A FLOW EVENT

Figure 1a shows the changes in total phosphorus, soluble orthophosphate, and suspended sediment with changes in flow for an event response river. Suspended sediment (SS) and total phosphorus (TP) transport in event response rivers are dominated by runoff events. It can be seen from Figure 1a that SS and TP concentrations increase with increasing flow. Soluble orthophosphate (OP) concentrations are seen to decrease during the flow event. The major



(a) SOUTH BRANCH CATTARAUGUS CREEK NEAR OTTO



(b) GRAND RIVER AT EASTMANVILLE

Figure 1 - Variation in Total Phosphorus, Soluble Orthophosphate, and Suspended Solids Concentration with Flow for (a) the South Branch of Cattaraugus River near Cattaraugus, NY, and event response river, and (b) the Grand River at Eastmanville, MI, a stable response river. Source: Reference (2).

portion of the phosphorus transport is with the sediment that originates from the runoff. The behavior of SS and TP in an event response river is markedly different than their behavior in a stable response river whose watershed has soils of coarse texture and high permeability (1). In these watersheds, water infiltrates instead of running off, and SS and TP concentrations do not show large increases with flow as shown in Figure 1b for the Grand River. In the Grand River, suspended sediment varies from 50 to 160 milligrams per liter and total phosphorus varies from 0.08 to 0.22 milligrams per liter as compared to a range of 120 to 1,100 milligrams per liter for suspended sediment and 0.16 to 0.78 milligrams per liter for total phosphorus in the South Branch of the Cattaraugus. Soluble orthophosphate concentrations are similar for both rivers. In the Grand River, approximately one third to one half the phosphorus transport is in soluble phase.

TOTAL PHOSPHORUS VS. SUSPENDED SEDIMENTS

As seen in Figure 1a, the SS and TP concentrations rise and fall together. Figure 2 shows a plot of the instantaneous TP and SS concentrations. Lower SS concentrations have a higher ratio of TP/SS than high SS concentrations. The reason for this behavior is that the higher SS concentrations are usually carried by higher flows which also carry larger particles. Also note that considerable variation in the TP/SS exists at lower flows. Table 1 shows the TP/SS ratios measured for Northwest Ohio rivers for the period 1975 to 1979. The ratios vary between the rivers and between years for each river. In light of the variation seen, caution should be exercised in picking TP/SS for use as a surrogate in the estimation of phosphorus loadings from suspended sediment measurements.

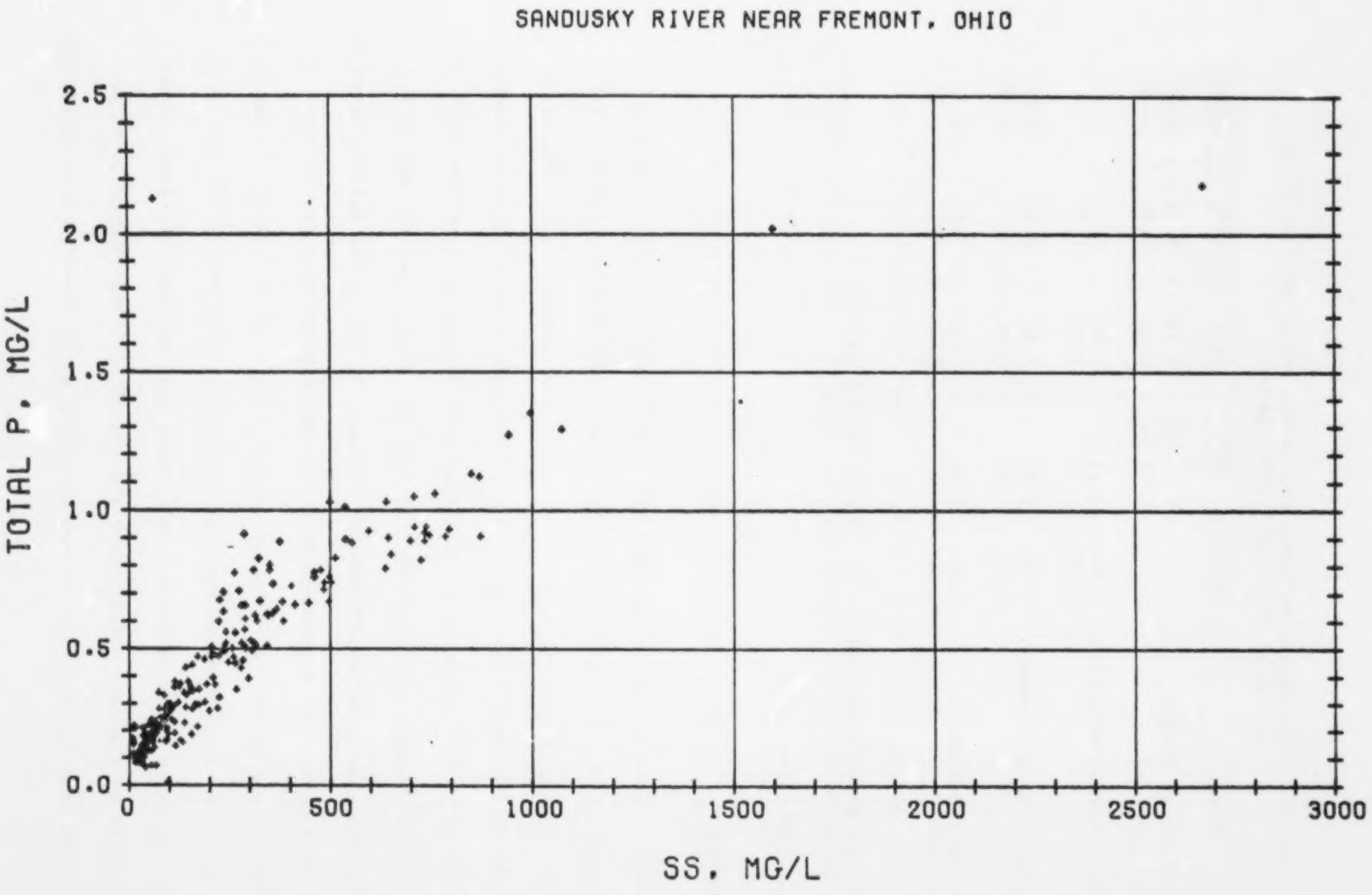


Figure 2 - Relationship of Total Phosphorus to Suspended Solids for the Sandusky River near Fremont, OH. Source: Reference (4).

Table 1 - Phosphorus Sediment Ratios for Northwest Ohio Rivers for Water Years 1975-1979 (gm/km)

River	1975	1976	1977	1978	1979
Honey Creek at Melmore	-	2.11 (1)	3.18	3.58	2.04
		1.83 (2)	2.08	2.40	1.72
Portage River at Woodville	1.84	2.45	2.54	2.77	-
	1.23	1.72	1.69	1.96	-
Sandusky River at Fremont	1.39	3.22	2.82	2.39	1.97
	1.15	2.81	2.10	1.78	1.58
Tymochtee Creek at Crawford	1.86	1.88	2.65	3.25	2.14
	1.64	-	2.03	2.27	1.77

(1) Total Phosphorus Load X 1,000/Suspended Solids Load
(2) (Total Phosphorus Load-Orthophosphate Load) X 1,000/Suspended Solids

Source: Reference 3

HYSTERESIS

From Figure 1a, it can be seen that the TP and SS concentrations peak before the flow. As a result, the same flow on the rising stage will carry a higher concentration than the same flow on the falling stage. This effect is shown in the hysteresis diagram shown in Figure 3 which plots TP concentration and SS concentration versus flow. The arrows begin at the start of the storm and point to increasing time into the storm. Another way of displaying the concentration differences between the rising and falling stage is shown in Figure 4 which presents least squares correlations for TP concentrations and river flow rate for different days of the storm. It can be seen that the steepest slope for this correlation line occurs for the first day of the storm. The second and third days have successively lower slopes. The scatter of the data points about the correlation line should be noted. It results from difference in stream chemistry among runoff events of similar

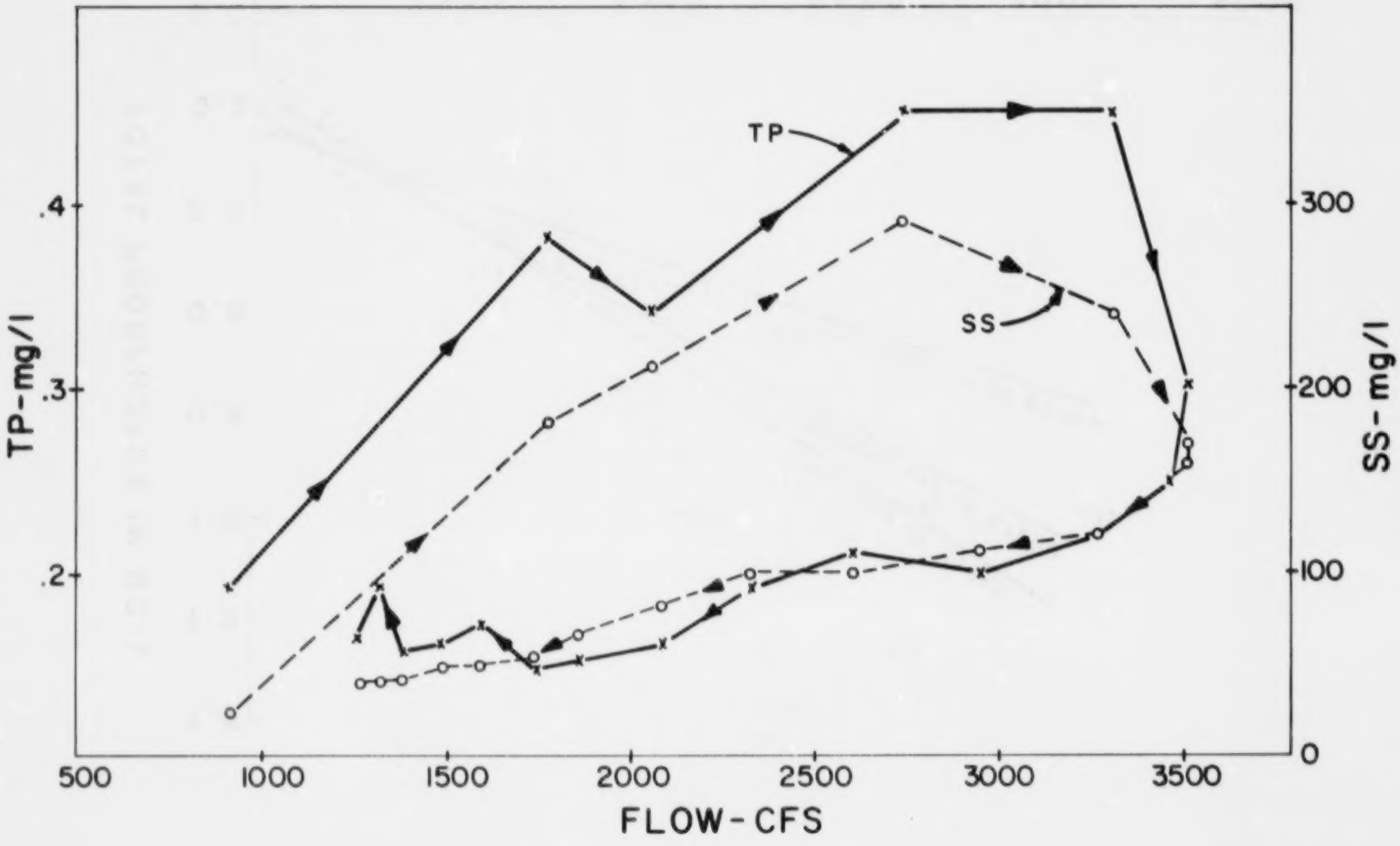

CLINTON RIVER AT MORAVIAN DRIVE
MT. CLEMENS, MICHIGAN
MARCH 28 - APRIL 1, 1977

Figure 3 - Hysteresis Diagram for Total Phosphorus and Suspended Solids as a Function of Flow.

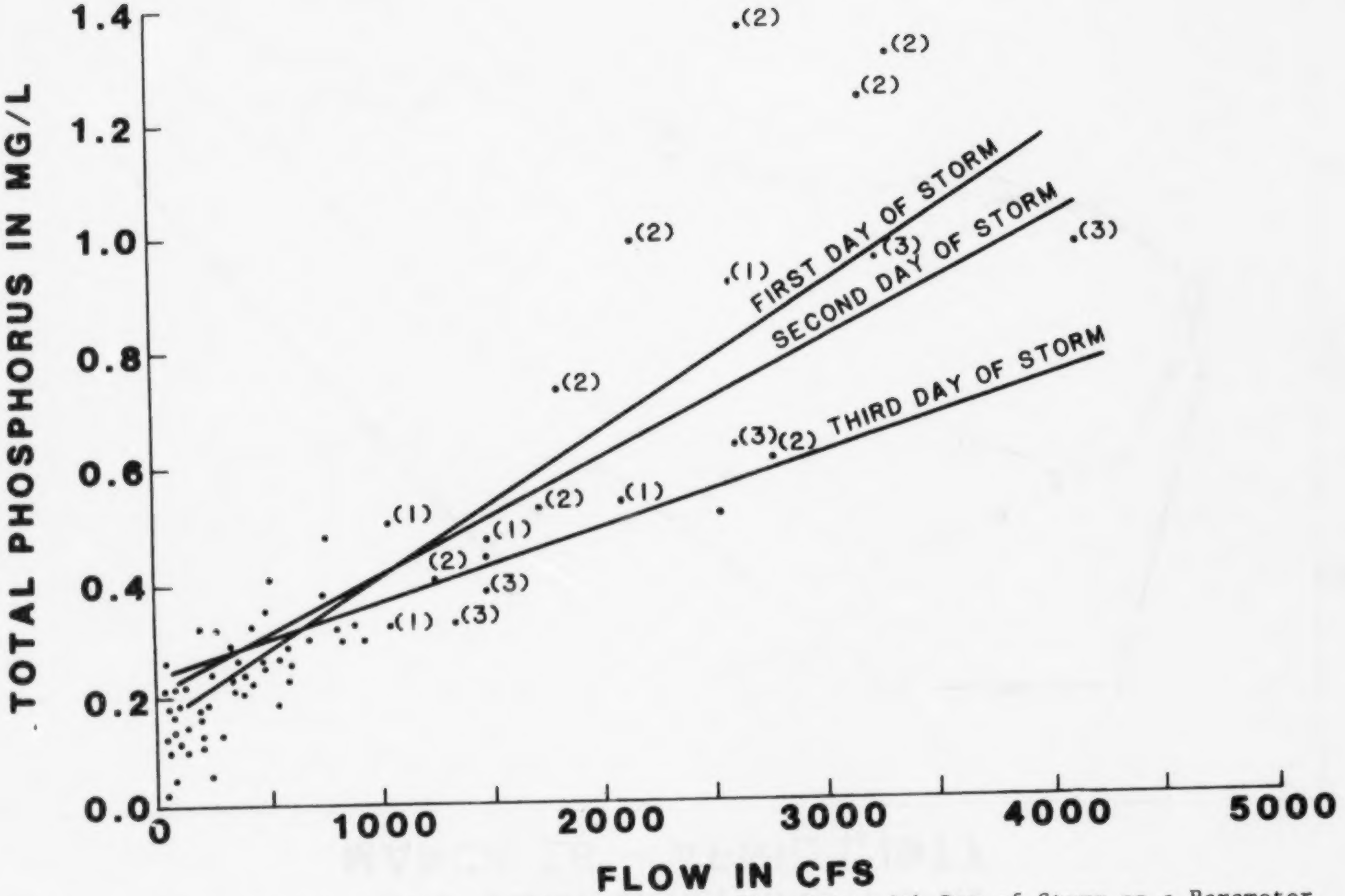


Figure 4 - Total Phosphorus Concentration vs. River Flow Rate with Day of Storm as a Parameter. The least squares correlations for each day of the storm is indicated. The number in parenthesis indicates the day of the storm. Source: Reference (5).

size and similarities in stream chemistry among runoff events of different size.

PATTERNS OF TRANSPORT

Figure 5 shows the patterns of TP concentration versus log flow for three river stations. Tymochtee Creek at Crawford is an example of an agricultural watershed with no significant point sources. TP concentrations are low at low stream flow and increase as the flow increases. The high TP concentrations at high stream flow reflect the combined effects of TP carried by the surface runoff which is producing the high flow and of suspended sediment carrying phosphorus suspended from the stream bottom by the stream current.

The Sandusky River at Upper Sandusky is an example of a sampling station in an agricultural watershed located a considerable distance downstream of point sources. The TP concentration shows a slight increase as flow decreases. At high flows, the TP concentration increases.

The Sandusky River at Bucyrus is an agricultural watershed where the sampling station is located a short distance downstream from a significant point sources of phosphorus. The TP concentration and log flow pattern for this station differs significantly from pure agricultural watersheds. At Bucyrus, the sampling station is approximately 1/2 mile downstream from the outfall of the Bucyrus Wastewater Treatment Plant. This plant has not yet initiated a phosphorus removal program although it has a mean daily flow of 2 million gallons per day. The TP concentration increases greatly as the streamflow decreases, due to decreasing dilution of the relatively constant effluent from the Bucyrus Wastewater Treatment Plant. The TP concentration

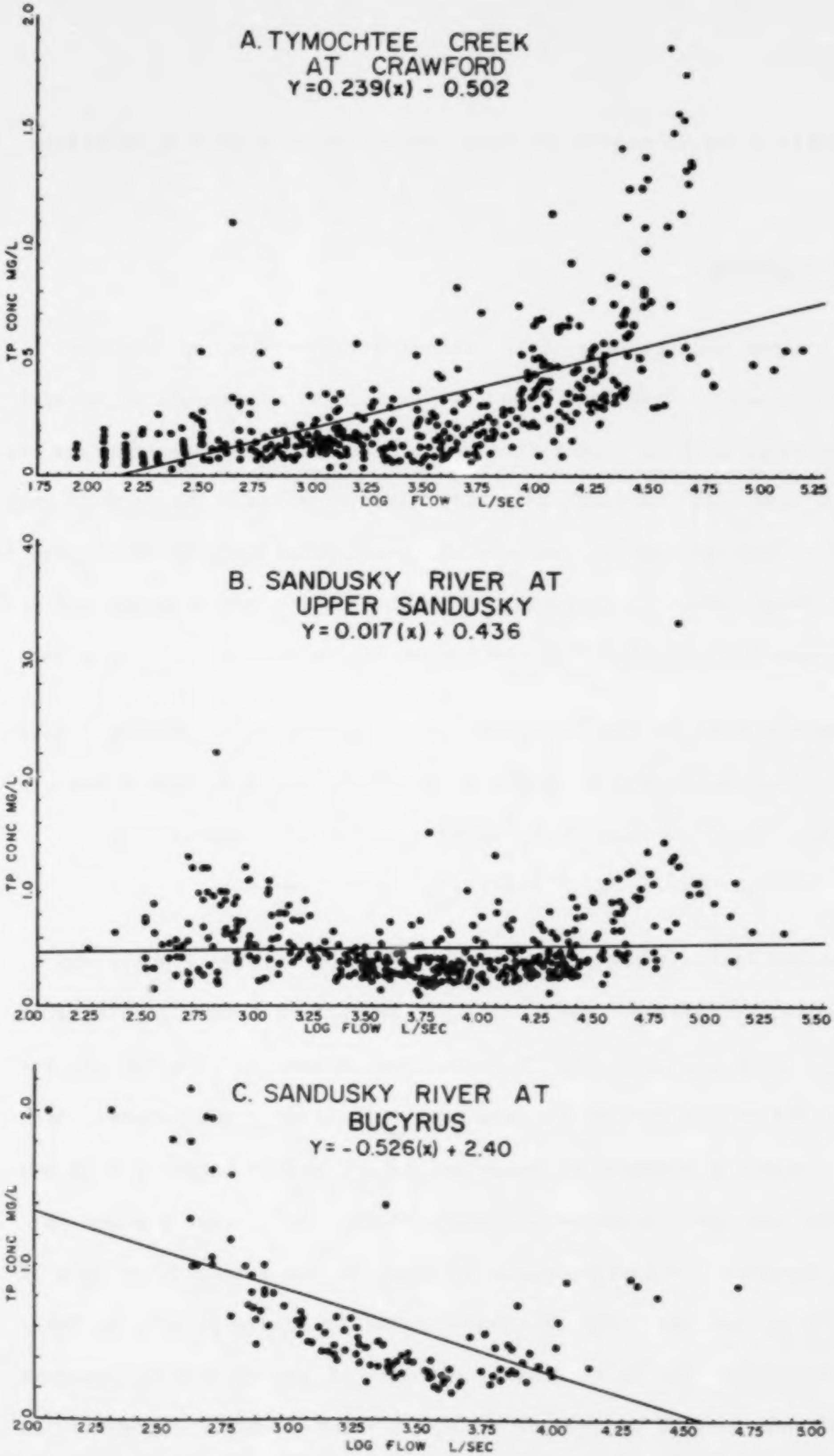


Figure 5 - Least Square Equations for Total Phosphorus and Log Flow:

(a) Tymochtee Creek at Crawford, an agricultural river basin.

(b) Sandusky River at Upper Sandusky, an agricultural river basin with upstream point sources.

(c) Sandusky River at Bucyrus, a station immediately below a point source.

Source: Reference (3).

also increases at high streamflow, but this effect is partially obscured by the extremely high concentrations under low flow conditions.

TOTAL PHOSPHORUS DEPOSITION

Figure 6 shows the TP concentrations downstream of the Bucyrus Wastewater Treatment Plant at Kestetter (0.9 km), Denzer (4.25 km), and Caldwell (6.53 km). Samples were collected every 2 hours for this study (7). The decrease in TP concentrations downstream is not due to dilution (increase in flow is insignificant) but deposition and biological processing. The diurnal variation in the concentrations at all three stations can be seen. Also noticeable is the displacement in the peaks as they move downstream.

In contrast to the well-defined picture of deposition, diurnal variation and downstream displacement of the concentration peak obtained from the 2-hour samples shown in Figure 6a is the data shown in Figure 6b. This data was collected by a grab sampling program at approximately 6-hour intervals. From this data, downstream deposition between Kestetter and Denzer is not noticeable. In fact, concentrations seem to be increasing between the stations. The reason for the large variation in concentrations is not obvious and the concentration peak is not seen to be moving downstream. Figure 6 is a good example of how a false understanding of a system can be obtained from an inadequate sampling program.

A TRANSPORT THEORY

DEPOSITION AND RESUSPENSION

The observations of transport just described can be used with mass and force balance equations to develop a theory of how phosphorus and suspended

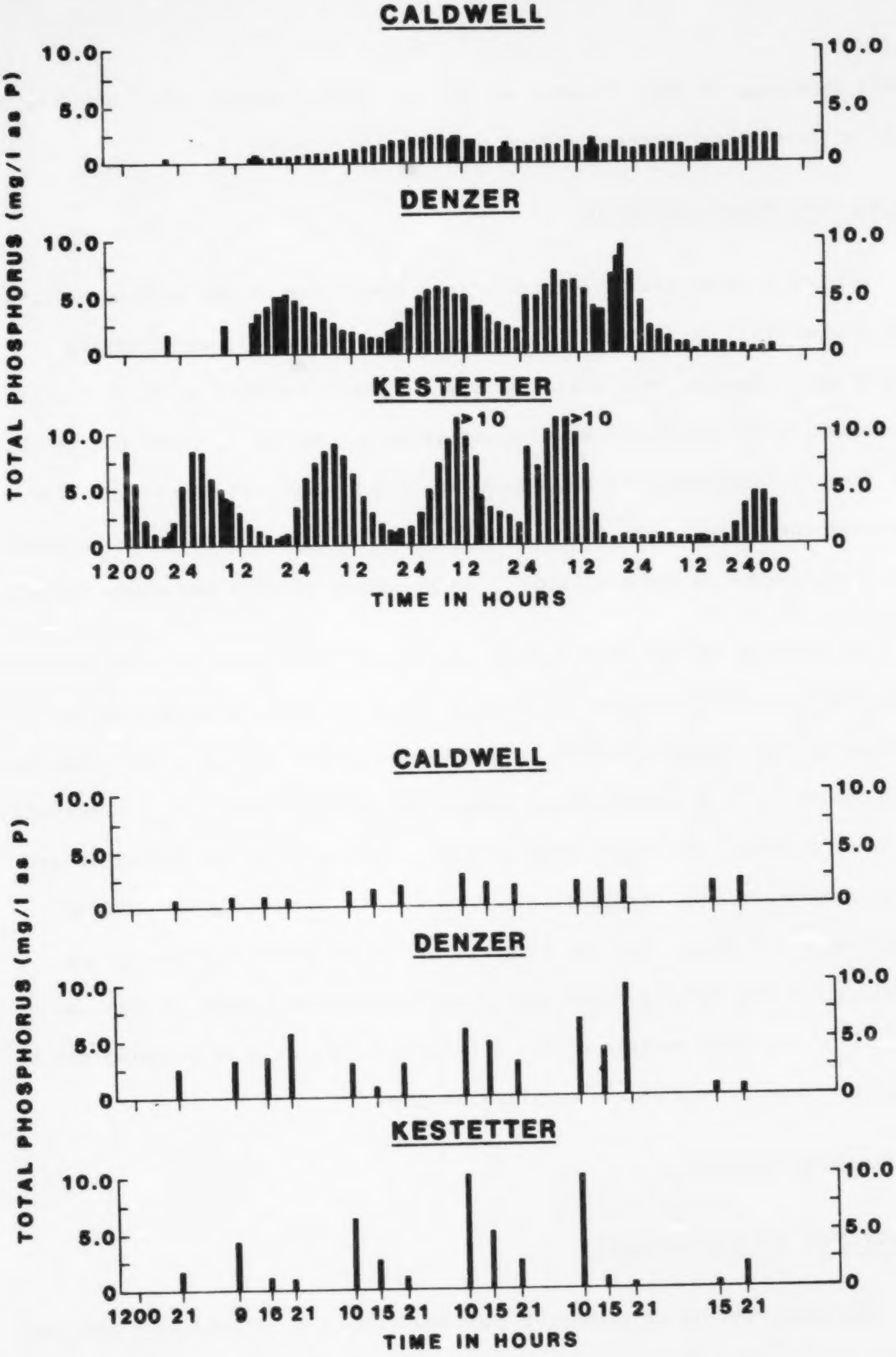


Figure 6 - Total Phosphorus Concentrations in the Sandusky River downstream of Bucyrus, Ohio. Kestetter (0.9 km), Denser (4.25 km), and Caldwell (6.53 km) - (a) at 2-hour intervals and (b) grab samples. Source: Reference (6).

sediment are transported in a river. The important characteristics used in developing the theory are: 1) the peak of the TP concentration usually leads the flow rate peak of the river at any station; 2) the TP concentration declines to its low flow value before the flow returns to its approximate steady flow range of values; and 3) the peak TP concentration is not necessarily higher at the downstream stations than at the upstream stations (8).

Figure 7 shows the results of calculations for different theories which explain the three characteristics described above. Figure 7a shows the initial conditions, a chemograph with the TP concentration peak ahead of the flow peaks. The results in Figure 7b indicate that after 40 miles downstream with no water or chemical input, the peak of total phosphorus has moved behind the peak of water flow. This result is in contrast with the observation that the TP peak is still ahead of the flow peak at downstream stations. Figures 7c and 7d compare models which would explain the fact that the observed TP peak does not lag behind the flow peak. Curves TP(1) and TP(2) assume local inflow with two different TP concentrations and no resuspension. Curve TP(1) has the TP concentration lagging behind the flow peak. Curve TP(2), which has the TP peak remaining ahead of the flow peak, does not have the TP concentration decreasing to its initial value. Both of these results are in disagreement with the observed facts. Only Figure 7d which assumes resuspension and deposition proportional to the rate of change of velocity with time reproduces the field observations. The peak in TP concentration remained ahead of the flow peak and the total phosphorus concentration declined with declining flow.

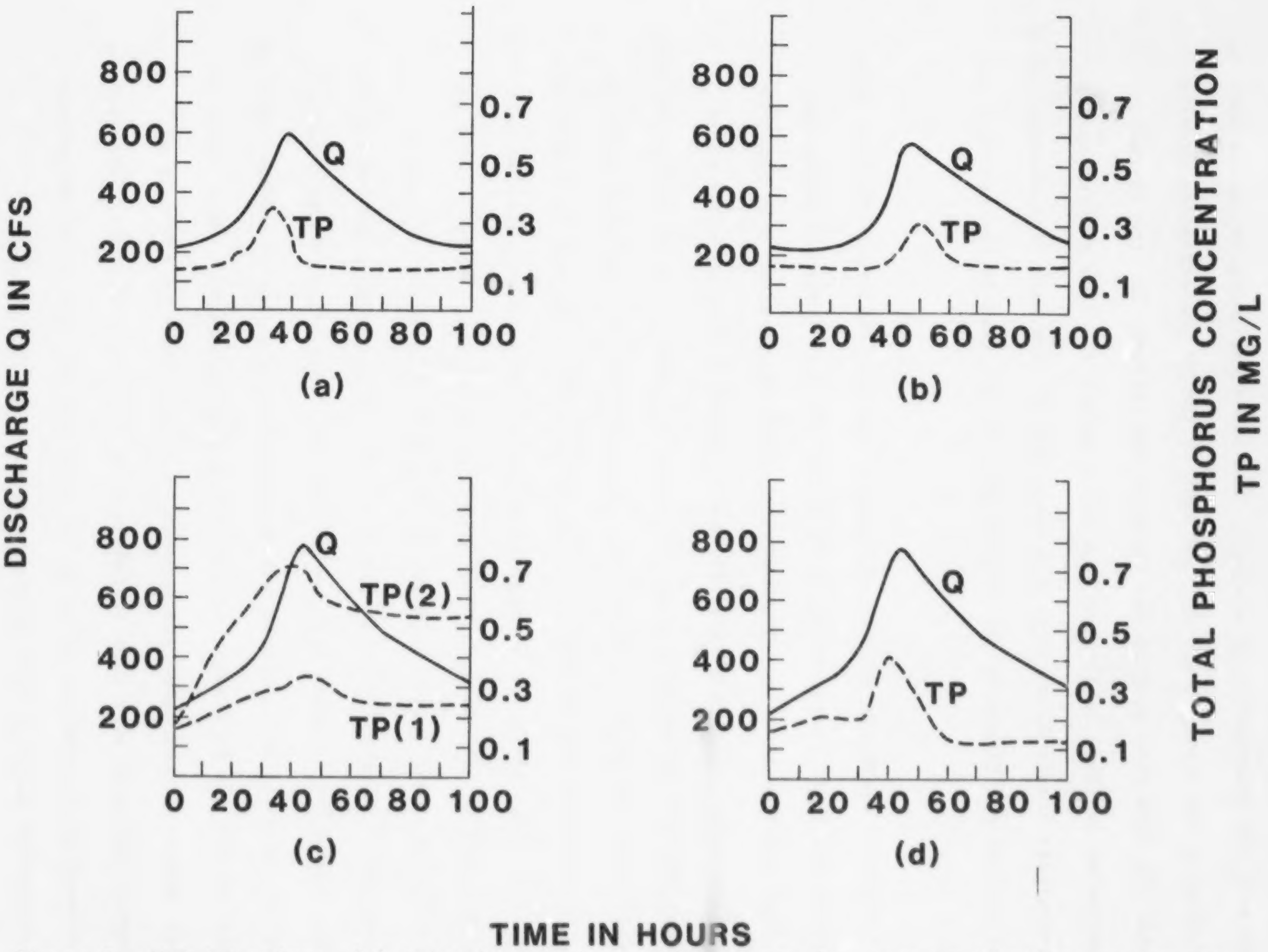


Figure 7 - Model Results: (a) initial conditions; (b) distance downstream = 40 miles, no inputs; (c) distance downstream = 40 miles, local inflow = 0.02 X Q cfs/mile, local total phosphorus inflow concentration, TP(1) = 0.375 mg/1, TP(2) = 1.015 mg/1; (d) same as (c) with TP = 0.1875 mg/1 with resuspension/deposition.

DISTANCE OF TRAVEL

From the previous discussion, it has been suggested that the transport of total phosphorus occurs via a mechanism by which the phosphorus is picked up at one point in the stream and deposited at another. Given that total phosphorus is transported from one point in the stream to another, the distance of transport becomes an important issue. This distance of travel could be measured experimentally for any given reach of stream by employing tracer particles. However, these distance estimates would be valid for only the individual stretch and numerous measurements would have to be made for different stream reaches just to understand one river basin. This same information can be estimated from the hydrograph and chemograph measured at a given point in a stream. The technique to be described uses the assumption that the water is moving as a kinematic wave. Furthermore, the actual distances calculated are derived from information obtained at one point in the river and hence the assumption that the whole stretch of river is similar to the measurement point is implied (9).

The calculational procedure is based upon two data sets; the time dependency of both flow and total phosphorus concentration, and the flow versus area curve for a rated point in the stream. From this information, the average distance traveled by the total phosphorus during a storm event can be calculated. Figure 8 shows the cumulative probability of travel distances at various stations in the Sandusky River basin for a storm event. It can be seen from this figure that 50 percent of the phosphorus from Bucyrus which was resuspended and measured at Upper Sandusky will move at least 52 miles, which is the distance to Lake Erie. The rest of this

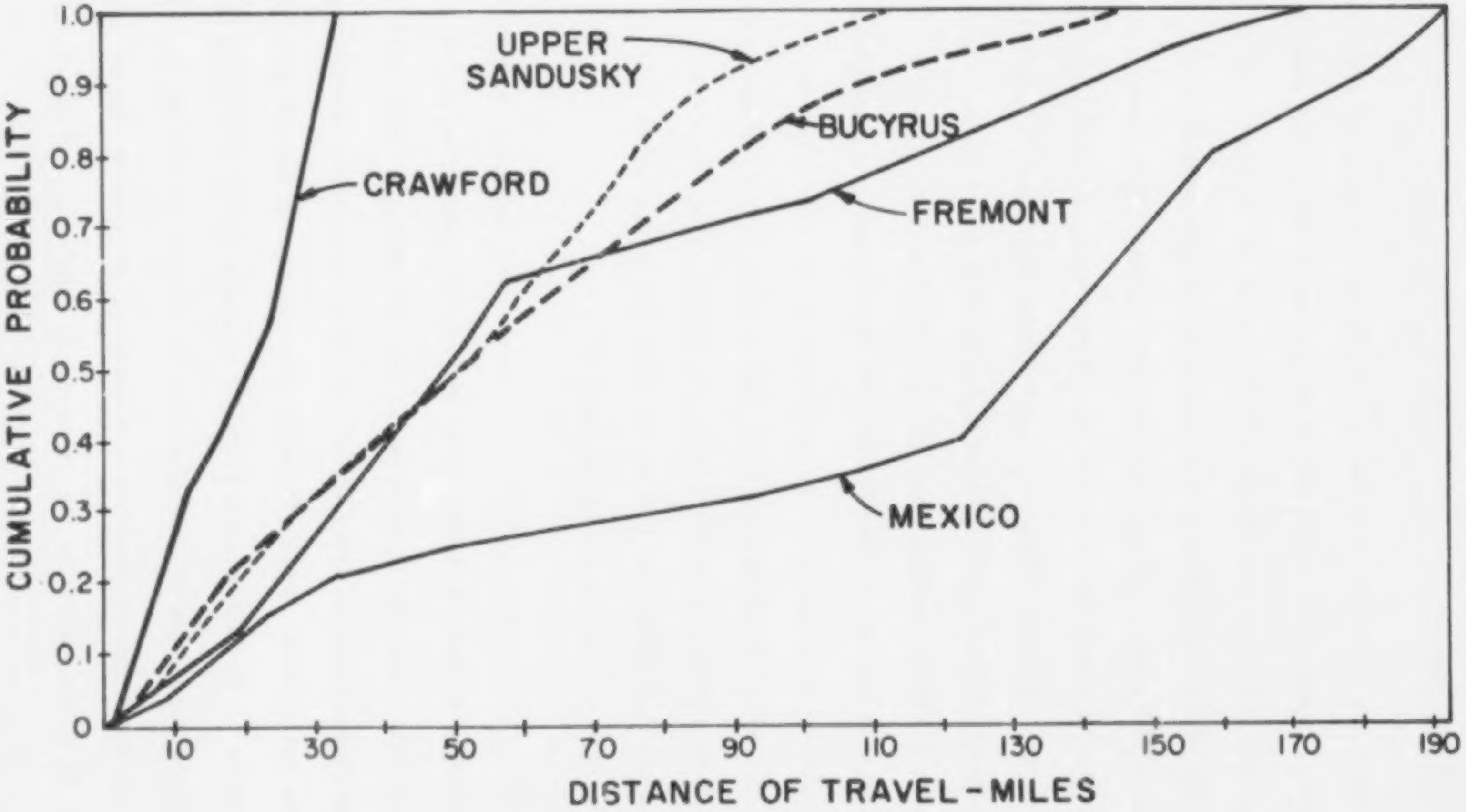


Figure 8 - Cumulative Probability that Total Phosphorus will be Deposited In-stream Before Traveling the Stated Distance. Sandusky River Basin, 12 July 1974. Source: Reference (9).

material will be deposited before it reaches the lake. Flows at least as great as the flow event for which these calculations were made occur on the average of nine times a year.

INSTREAM PROCESSING

The steady state deposition studies (Figure 6) show orthophosphate and total phosphorus discharged from a sewage treatment plant are rapidly removed from the water column (7). As this material moves downstream from the outfall, it is adsorbed to river sediments by clay minerals and/or micro-organisms. Calculations show that about 75 percent of the total phosphorus is lost after traveling 16 kilometers during low flow conditions which occur 35 percent of the time (10). At these periods, Lake Erie or stations located 16 or more kilometers downstream do not experience increased phosphorus concentrations resulting from point sources.

The phosphorus deposited in the river bottom sediments during steady state conditions is resuspended during high flow events. This phenomenon can be seen in Figure 9 which shows deposition and resuspension of total phosphorus and orthophosphate between Bucyrus and Upper Sandusky on the Sandusky River. Deposition and resuspension were calculated utilizing a dynamic phosphorus transport model (11). This model routes all upstream inputs between Bucyrus and Upper Sandusky to Upper Sandusky. If the routed sum is larger than what was actually measured, deposition is assumed. If what is measured is larger than the routed sum, resuspension is assumed. It can be seen from Figure 9 that both total phosphorus and orthophosphate are lost from the water during low flow. However, during high flow, only total phosphorus is resuspended. Orthophosphate is neither deposited to nor

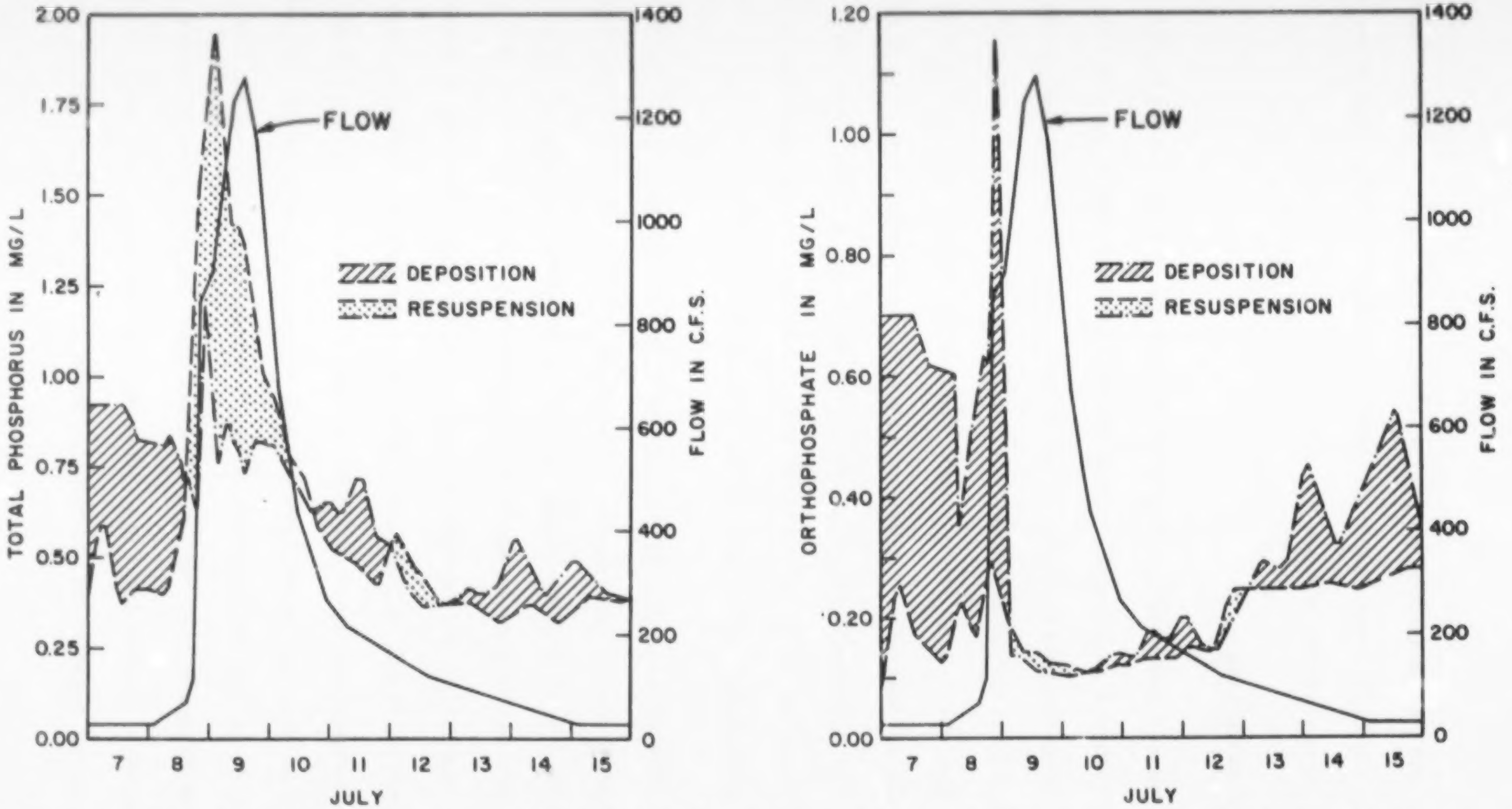


Figure 9 - Deposition and Resuspension of (a) Total Phosphorus and (b) Orthophosphate in the Sandusky River near Upper Sandusky - Storm beginning 7 July 1976. Source: Reference (11).

released from the sediments during high flow. It moves right through the system. This figure very clearly illustrates the instream processing of nutrients. Immediately available orthophosphate is converted to potentially available sediment phosphorus during steady state flow conditions. The phosphorus is later transported as potentially available sediment phosphorus during high flow. It also should be noted that during high flow, phosphorus from point sources is transported directly through the river with no instream processing.

SAMPLING STRATEGIES FOR FLUX ESTIMATION

It has been shown in the previous sections that SS and TP transport in an event response river occurs in a river during high flow events by a process of resuspension and deposition. Knowledge of when the material is moving can help to determine when to sample.

FIXED INTERVAL SAMPLING

Treuner et al. (12) examined the effect of sampling frequencies on determination of annual phosphorus load of small to moderate streams (Wahnbach River in Germany) with low flows and no relationship between total phosphorus concentration and flow (stable response river). They examined sampling frequencies of 1 to 29 day intervals between measurements. They also examined four different averaging methods to determine annual loads. They concluded that use of continuous flow measurement by means of a level recorder leads to annual total phosphorus loads two to four times more accurate than discontinuous flow measurements with a simple measuring weir. In addition, they concluded that sample frequencies of 14 to 21 days (17 to

21 samples) and continuous flow measurements with a level recorder are required to keep deviations within 20 percent of the reference value (Figure 10).

In contrast to the above results, Hetling, et al. (13) concluded that a fixed interval sampling is of little value to obtain annual loads unless daily or every other day samples are taken. With sample frequencies of 14 to 21 days (17 to 21 samples) deviations of 700 percent were obtained for particulate phosphorus and 1,700 percent for suspended sediment for an event response river (Figure 11). They further concluded that a sampling strategy based on sampling high flow events was necessary to obtain reliable annual load for an event response river.

HIGH FLOW SAMPLING

Assuming that high flows must be sampled, the question arises as to how many samples are required. Figure 12 shows the percent deviation from the true value for event sampling strategies for four event response rivers (Maumee, Portage, Sandusky, and Huron). The figure was developed by using only the data collected during the largest and/or second largest flow events plus a few low flow samples. The flow interval method (14) was used to make a flux estimate and from this, a flux calculated from the complete yearly record was subtracted. The difference was divided by the flux calculated from the total record.

It can be seen from the figure that for all three parameters all but two estimates are within a 50 percent deviation, and most of the estimates are within 20 percent. In most cases, the error estimates overlap the

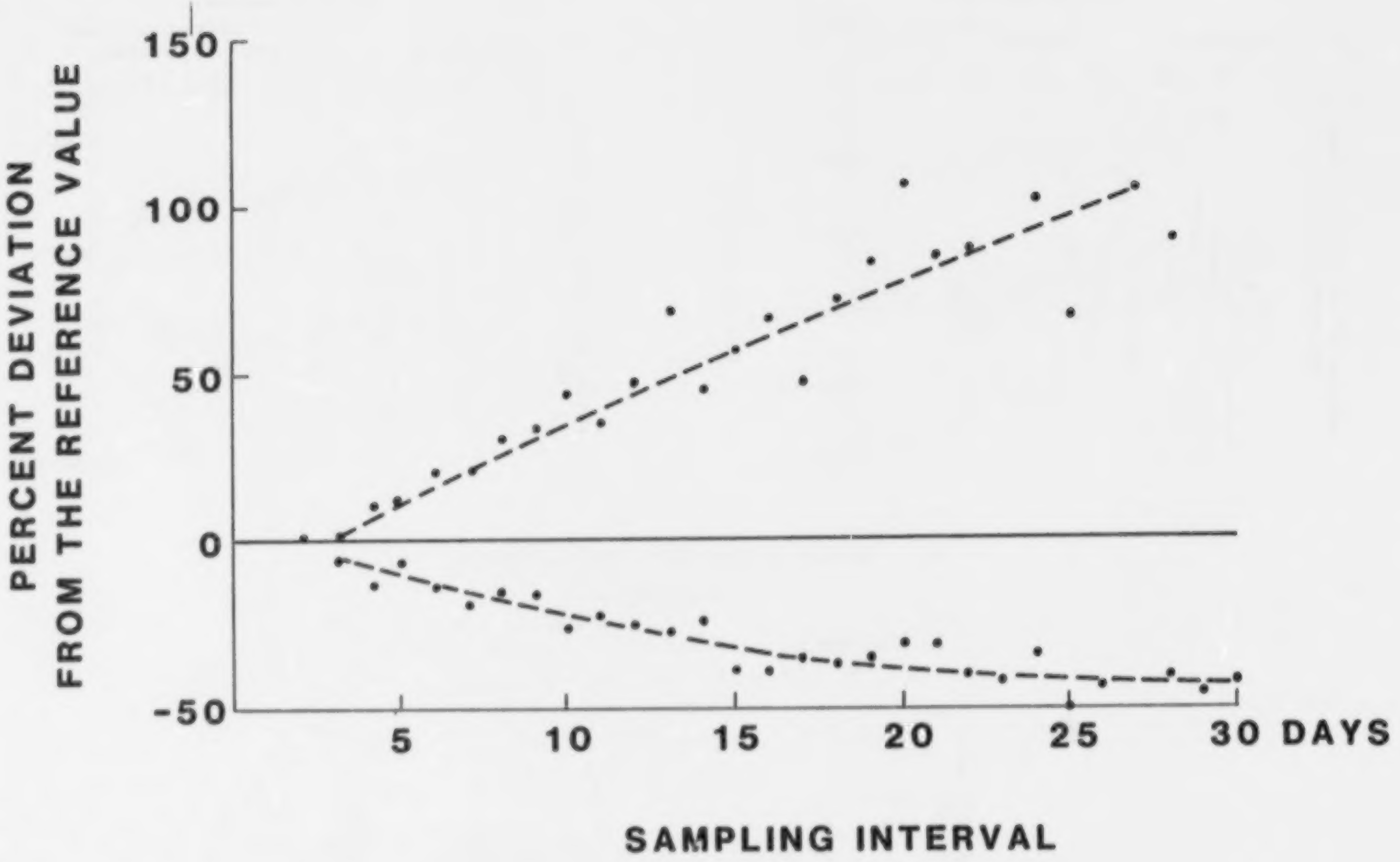
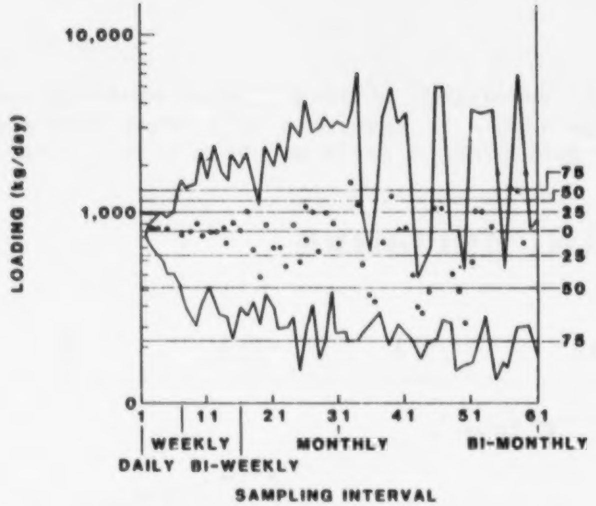
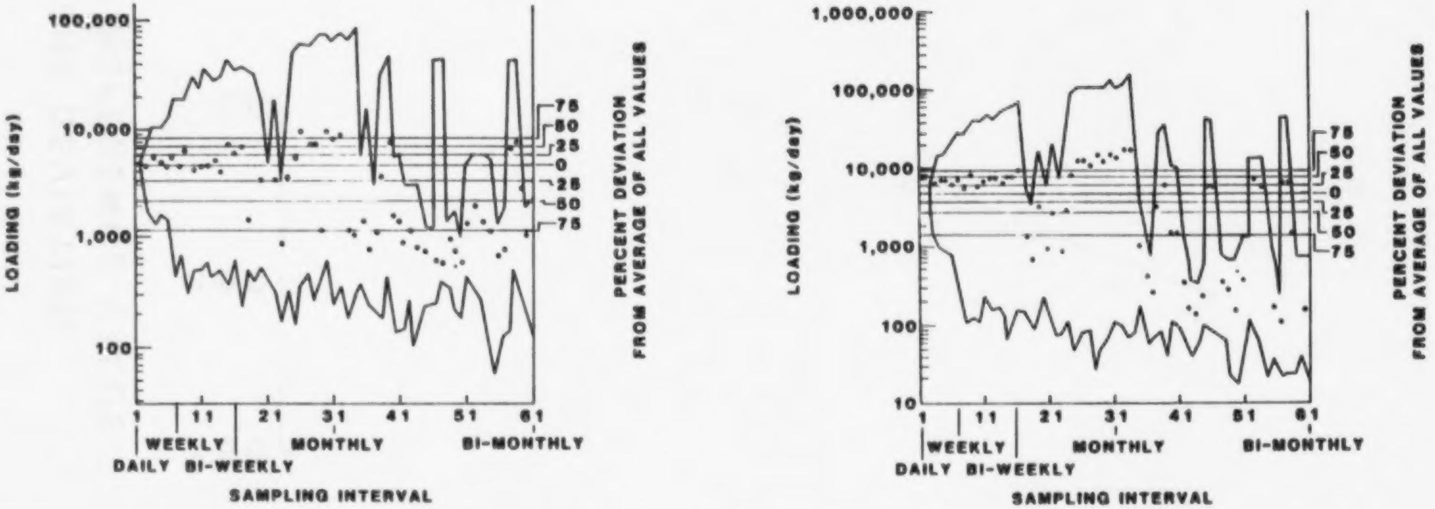


Figure 10 - Wahnbach River, a Stable Response River - Deviations of the annual P loads calculated from fixed interval sample sets taken from the total data base of daily samples. Total data base was used to calculate the reference value. Source: Reference (12).



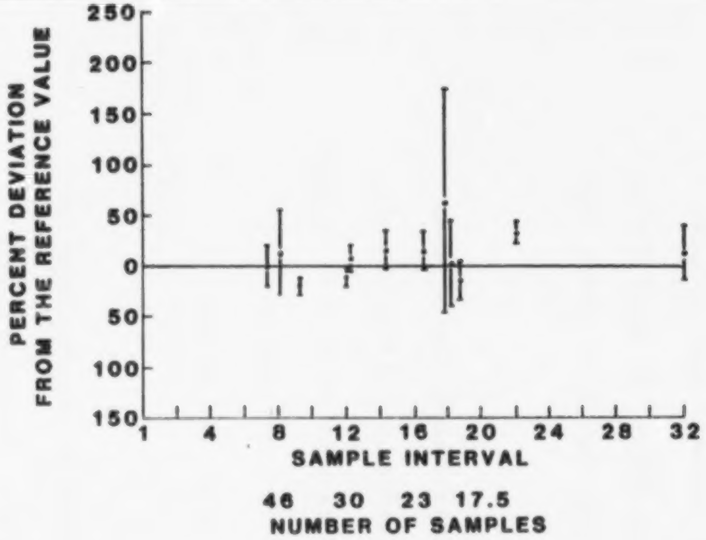
(a) DISSOLVED PHOSPHORUS LOADS



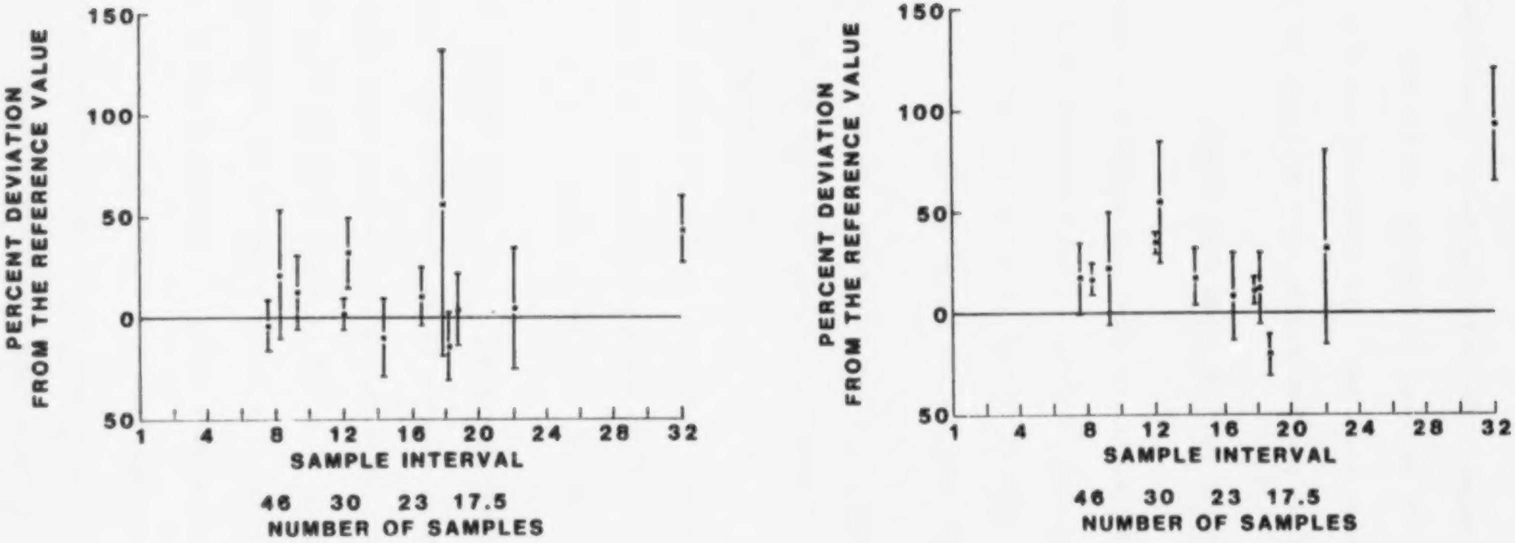
(b) PARTICULATE PHOSPHORUS LOADS

(c) SUSPENDED SOLIDS LOADS

Figure 11 - Mill Creek, an Event Response River - Deviations of the annual loads calculated from fixed interval sample sets taken from the total data base of daily samples. The total data base was used to calculate the reference value (a) Suspended Sediment; (b) Soluble Ortho Phosphate; and (c) Total Phosphorus. Source: Reference (13).



(a) SUSPENDED SEDIMENT



(c) TOTAL PHOSPHORUS **(b) SOLUBLE ORTHOPHOSPHORUS**

Figure 12 - Event Response Rivers - Maumee, Portage, Sandusky, and Huron Rivers. Deviations of the annual load calculated from data sets for the largest and/or second largest event. The total data base was used to calculate the reference value. (a) Suspended Sediment (b) Soluble Ortho Phosphate and (c) Total Phosphorus.

true value. The error estimate is calculated assuming a normal distribution and a 90 percent confidence coefficient. In contrast to the large variations obtained from the fixed interval sampling shown in Figure 11, the event sampling program yields very reliable estimates.

EFFECT OF MISSING HIGH FLOW EVENTS

Suspended sediment and material transported by sediment such as total phosphorus increase in concentration with increasing flow. If water quality measurements for these parameters are not made during high flow events, the annual load can be significantly underestimated.

Table 2 shows the total phosphorus load which was transported by Lake Erie tributaries during high flow events. For these event response rivers, 28 to 47 percent of the total phosphorus load was transported in 7 to 10 days during the year. If samples collected during high flow periods were not used in the loading calculation, total phosphorus loads can be underestimated at 15 to 30 percent.

There are a number of event response rivers which are heavily impacted by point sources (i.e., Sandusky River below Bucyrus). In these rivers, total phosphorus concentrations first decrease with increasing flow (due to dilution of point sources) then increase with increasing flow during a runoff event. In these river, event sampling is not as important as in other event response rivers. Another group of rivers in which event sampling is not as important are stable response rivers. They are primarily fed by ground water, not runoff, and sediment concentrations do not vary greatly with changing flow conditions (Figure 1b).

Table 2 - Total Phosphorus Transport During High Flows*

River	Percent Load	Percent Time	Percent Loss if Not Included in the Loading Calculation
Maumee	33	2.7	23
Portage	46	2.6	29
Sandusky	41	3.4	22
Huron	38	1.9	19
Vermilion	28	2.5	17
Chagrin	32	2.5	16
Cattaraugus	47	1.9	29

*Statistics for flows greater than 40 percent of the maximum flow for the period June 1974 to May 1975.

HYDROLOGICAL VARIABILITY

The annual load for any water quality parameter can vary considerably from year to year and river basin to river basin. The reason for this annual variation is the type and amount of rainfall which falls on the drainage basin and the condition of the basin when it rains. Annual changes in basin condition can result from natural or man-made causes. Basin soil moisture, infiltration capacity, and surface cover can be affected by climatic factors such as air temperature, sunshine, and previous rainfall. An example of man-made induced changes which affect basin conditions are changes in land use which can destroy cover over large areas, as during timbering operations or construction activities. Land use changes can also reduce the infiltration capacity when streets and homes are built. Surface cover and interception can be affected by changes in cropping patterns and tillage methods. Tillage methods can also change soil structure, thereby affecting the infiltration capacity and total porosity of a soil.

Moderate changes in the total amount of rainfall can have large changes in the total runoff from a basin. Not only does total runoff affect pollutant export, but the type of storms and when and how they occur will affect export. Two inches of rain falling in 1 hour may erode and transport much more sediment than 2 inches of rain over 24 hours. The same 2 inches per hour will cause much more erosion when the soil is bare and saturated than when there is surface cover and low soil moisture.

TIME VARIABILITY WITHIN A RIVER BASIN

An example of annual variation is shown in Figures 13a and b which show the long-term annual flow and annual suspended sediment record for the Maumee River at Waterville, Ohio. These flow data were collected with a recording level gage. The suspended sediment data were collected daily with additional measurements made during high flows. It can be seen from the figure that the mean annual flow was 4,886 cfs for the period of record. The minimum annual flow recorded was 1,996 cfs and the maximum was 8,587 cfs, a 430 percent variation. For suspended sediment, the mean annual load was 1,140,000 metric tons per year. The minimum load was 260,000 metric tons per year and the maximum load was 2,106,000 metric tons per year, a variation of 23 to 185 percent of the mean annual load.

Annual variations in nutrient transport are not as extreme as those in sediment transport. Table 3 shows the annual and sediment flows and nutrient and sediment flux for the Sandusky River at Fremont. It can be seen from

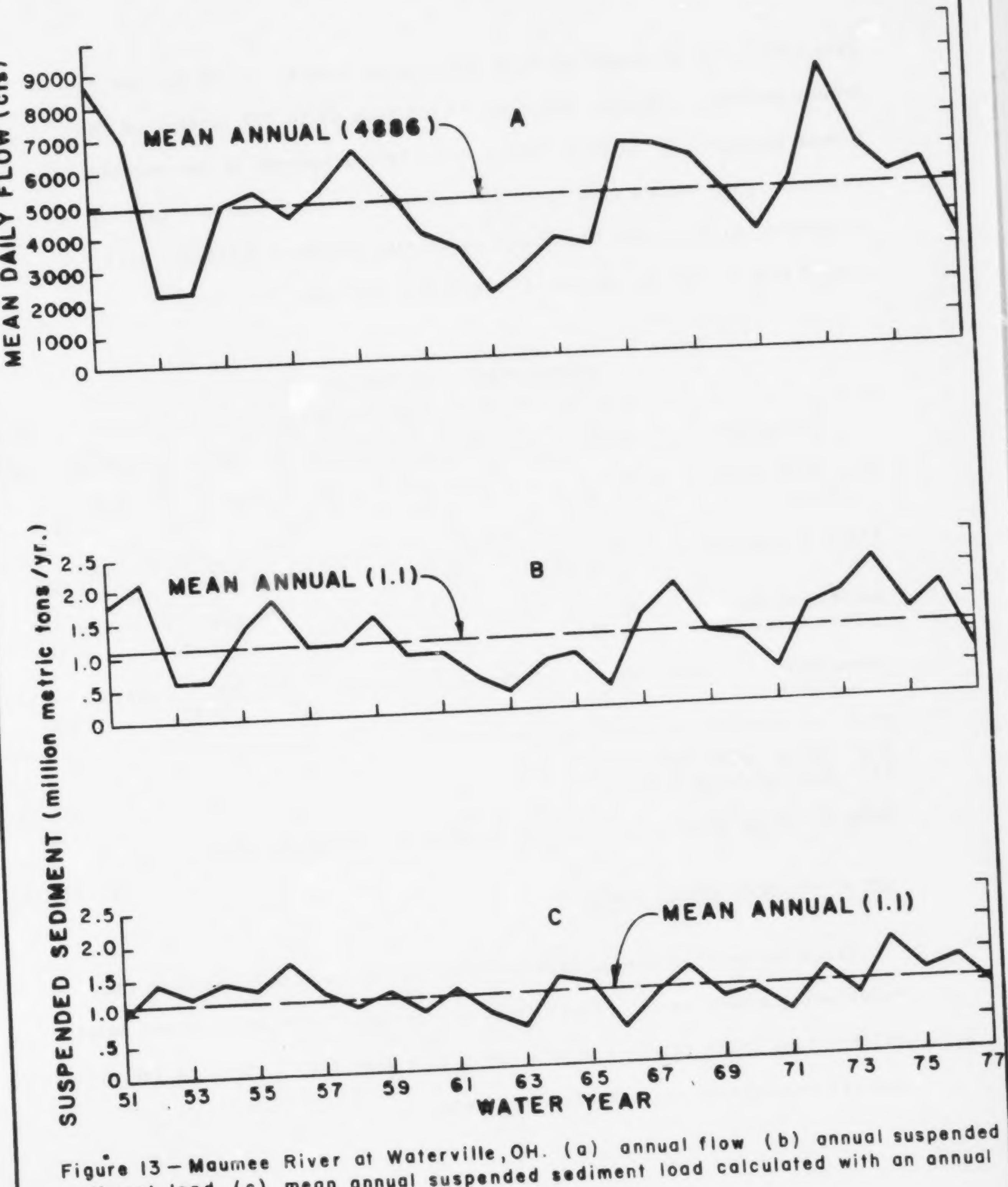


Figure 13 — Maumee River at Waterville, OH. (a) annual flow (b) annual suspended sediment load (c) mean annual suspended sediment load calculated with an annual weighted mean.

this table that although the flow only varied from 64 to 142 percent of the 5-year average, suspended sediment varied from 49 to 150 percent of the 5-year average. Total phosphorus, which is transported by the suspended sediment, only varied from 61 to 134 percent of the 5-year average. Orthophosphate, which is not transported with the suspended sediment, only varied from 60 to 140 percent of its 5-year average.

Table 3 - Nutrient and Sediment Transport for the Sandusky River at Fremont

Parameter	1975	1976	1977	1978	1979	5-Year Average
Flow (10^6 cubic meters)	1,030 1.05	772 0.79	629 0.64	1,390 1.42	1,090 1.11	981
Total Phosphorus	419 (1) 1.00 (2)	399 0.95	258 0.61	463 1.10	563 1.34	420
Soluble Ortho Phosphorus	72 0.86	50 0.60	66 0.79	117 1.40	112 1.34	83
Suspended Sediment	302,000 1.50	124,000 0.62	98,800 0.49	194,000 0.97	286,000 1.42	200,800

(1) Metric tons/year
(2) Annual/5-year average

Source: River Laboratory, Heidelberg College. Reference (3).

ANNUAL VS. MEAN ANNUAL LOADS

Calculation of an annual load for a river is a different problem than calculating a mean load. Annual loads are necessary for mathematical model calibrations which relate 1 year's input to a lake from a river to the water quality measured in the lake for that year.

However, annual loads are not useful for determining the distribution between point and nonpoint sources of total phosphorus inputs to a lake. For example, the nonpoint source load to Lake Erie varied between 40 and 57 percent of the total lake load between 1970 and 1977 (10). Depending upon what year is chosen, opposite conclusions could be reached: control of diffuse sources is required to restore the lake or control of diffuse sources is not required to restore the lake. To make a judgment on the need for diffuse source control, a mean annual load is needed.

EFFECT OF FLOW VARIATION ON ANNUAL LOAD

With large variations in annual load, the question arises, "How can an annual load estimate be normalized to a mean load estimate?" One way to normalize an annual load estimate is to calculate the annual weighted mean concentration (annual load divided by annual flow) and multiply it by the mean annual flow. This mean annual load for the Maumee River suspended sediment data is shown in Figure 13c. It can be seen from the figure that this estimate of mean annual load varies from 485,000 to 1,668,000 metric tons per year. This estimate of annual load is more representative of export from the basin, but still has a variation of 43 to 146 percent of the mean annual load.

Use of an annual weighted mean concentration to calculate a mean annual load removes variations in total annual flow from the mean annual load estimate. However, variations in mean annual loads still exist and result from differences in flow characteristics such as the magnitude, duration, frequency, and seasonal distribution of high flow events. Therefore, if material export from a basin is to be adequately characterized, these differences in annual flow characteristics must be eliminated.

When more than 1 year of concentration data is available, the entire data set should be used to calculate a flow weight mean concentration which can be used with mean annual flow to calculate a mean annual load.

VARIABILITY BETWEEN RIVER BASINS

Sediment, nutrient, and chemical export from rivers is often compared on a unit area basis, i.e., the export measured at a flow gaging station is divided by the area of the river basin above the station. Often, unit area loads measured in one river basin are used to estimate flux from unmeasured watersheds. Table 4 shows the unit area contributions of total phosphorus from nine rivers which flow into Lake Erie. For the 2 years shown, the annual unit area loads range from 0.75 to 3.57 kilograms per hectare. This range of variation is typical of the range of unit area loads which can be expected from rivers in the same region. Considerable care should be exercised before using unit area loads to calculate fluxes in unmeasured rivers.

The mean annual loads shown in Table 4 do not show as much variation as the annual loads. They were calculated from the flow and concentration data collected during 1975 to 1977 and the period of record flow duration tables. The mean annual total phosphorus loads only vary from 0.79 to 1.65 kilograms per hectare. If unit area loads must be used, mean annual loads would provide a better estimate than annual unit area loads.

Also shown in Table 4 is the unit area diffuse source load. This load was calculated by subtracting the upstream point sources from the annual load. The diffuse source load varies from -0.45 to 1.06 kilograms per hectare per year. This range of variability is greater than that shown by the mean annual load. The negative loads indicate that all of the point source phosphorus is not being delivered to the measuring station. It is moving into long-term storage in either the streambed or the flood plain. In summary, unit area loads are not a reliable source of data to make flux estimates for unmeasured rivers.

Table 4 - Unit Area Contributions of Total Phosphorus

	Kilograms as Phosphorus Per Hectare Per Year (kg/ha/yr)			
River	1975 (1)	1977 (1)	Mean Annual (2)	Diffuse Source (3)
Maumee	1.58	1.15	1.12	0.86
Portage	1.25	0.99	0.79	-0.16
Huron	1.20	1.15	0.81	0.63
Sandusky	1.61	0.75	.91	0.45
Vermilion	1.89	1.03	0.71	0.48
Black	1.89	1.65	1.10	0.86
Cuyahoga	3.57	1.57	1.65	-0.45
Chagrin	1.76	0.98	1.00	0.76
Cattaraugus	1.31	2.25	1.06	1.06

(1) Water year, 1 October to 30 September.
(2) Calculated with the concentration and flow data collected in 1975 to 1977 and the period of record flow duration tables.
(3) The diffuse source load was calculated by subtracting the upstream point source load from the mean annual load.

Source: Reference (10).

CONCLUSIONS

The information described in this paper resulted from an attempt to answer the question, "How much phosphorus from tributary point sources reaches the lake?" The answer to the question still is, "We don't know." Despite the answer being the same, our knowledge of sediment and phosphorus transport in rivers has increased. Based on the work described in this paper, the following conclusions can be reached:

1. Two types of rivers exist - event response rivers where SS and TP concentrations increase with increasing flow, and stable response rivers where suspended sediment and total phosphorus concentrations do not increase with increasing flow. The type of river affects how you measure it.

2. In event response rivers, the bulk of the phosphorus is transported by the sediment. However, the total phosphorus/suspended sediment or (total-ortho phosphorus)/suspended sediment ratio varies considerably during an event, between events, annually, and between rivers.

3. Considerable variation in the flow concentration relationship for a river exists. This variation is caused by differences between the rising and falling limbs of individual runoff events, differences in stream chemistry among runoff events of similar size, and similarities in stream chemistry among runoff events of different sizes.

4. Different patterns of concentration versus flow exist between river basins with no upstream point sources, point sources immediately upstream, and point sources considerably upstream.

5. Both soluble and particulate phosphorus which enters a river during low flow is quickly removed from the water column. During high flow, the phosphorus is resuspended and subsequently transported as particulate phosphorus. This conversion from immediately available soluble orthophosphate to potentially available particulate phosphorus represents an instream processing of soluble orthophosphate from point and nonpoint sources.

6. Sediment and phosphorus in suspension travels a finite distance. The probability it will travel a certain distance can be calculated. This probability will change and vary between events and rivers. However, how long the material will remain on the bottom before being resuspended cannot be calculated.

7. High flow events must be sampled on event response rivers to obtain reliable suspended sediment and total phosphorus flux estimates. If these events are not sampled, fluxes will be underestimated by 15 to 30 percent.

8. Considerable diurnal variation can exist during low flow at river stations below point sources. Sample intervals as small as 2 hours may be required for some studies.

9. Annual orthophosphate, total phosphorus, and suspended sediment fluxes can vary considerably. A flux measured in any 1 year may not represent long-term transport for a river basin. A more representative calculation is a mean annual load.

10. Unit area loads vary between river basins. Caution should be exercised in using unit area loads measured for other watersheds.

RECOMMENDED SAMPLING PROGRAM

In order to obtain a reasonable estimate of total loads transported by an event response river, sampling during high flow events is necessary. Approximately two to three of the largest events must be sampled for a yearly estimate, with 15 to 20 grab samples collected over each hydrograph. An additional 5 to 10 samples should be collected during steady flow periods. This program should yield a loading estimate with an error estimate of 10 to 20 percent.

Fluxes for stable response rivers can be estimated with fixed interval sampling programs. The number of samples required will depend upon the variability of each river and will range from 15 to 45.

The above program will result in annual estimates for tributaries which are reliable and estimates which can also be used to detect differences in annual loads. However, this program will likely not be sufficient to detect progress made in control of diffuse sources. Annual variations in the frequency and duration of high flow events as well as basin conditions, such as soil moisture and cover, make any simple evaluation of change in phosphorus and sediment loads impossible. If changes in phosphorus loads are to be measured, continuous records of rainfall, streamflow, water quality, soil moisture, and cover will be needed, as well as improved methodologies for relating this information. A few watersheds should be selected for such studies.

Progress in diffuse source control can best be assessed through monitoring the implementation of conservation measures in the agricultural community and storm water management controls in the urban areas. Intensive monitoring programs to accurately measure river loadings could be carried out on selected rivers as described above. Implementation of conservation measures can be used as input to models or tools, such as the Universal Soil Loss Equation, to estimate progress based on reductions in potential gross erosion.

REFERENCES

(1) Sonzogni, W. C., et al., "United States Great Lakes Tributary Loadings," PLUARG Technical Report, Ann Arbor, Michigan, January 1978.

(2) USEPA Region V - STORET Retrieval.

(3) Baker, D. A., Heidelberg College River Laboratory, Tiffin, Ohio.

(4) U. S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study, Preliminary Feasibility Report, Buffalo, New York, 1975.

(5) Verhoff, F. H., S. M. Yaksich, and D. A. Melfi, "Phosphorus Transport in Rivers," Lake Erie Wastewater Management Study Technical Report, U. S. Army Corps of Engineers, Buffalo, New York, November 1978.

(6) Baker, D. A. and J. W. Kramer, "Patterns of Variability in Stream Chemistry Data," Lake Erie Wastewater Management Study Technical Report, U. S. Army Corps of Engineers, Buffalo, New York, March 1979.

(7) Verhoff, F. H. and D. A. Baker, "Moment Analysis for Review Model Discrimination and Parameter Estimation with Application to Phosphorus," accepted for publication with Water Research.

(8) Verhoff, F. H. and D. A. Melfi, "Total Phosphorus Transport During Storm Events," ASCE, Journal of the Environmental Division, October 1978.

(9) Verhoff, F. H., D. A. Melfi, and S. M. Yaksich, "Storm Travel Distance Calculations for Total Phosphorus and Suspended Materials in Rivers," Water Resources Research, Vol. 15, No. 6, December 1979.

(10) U. S. Army Corps of Engineers, Buffalo District, "Lake Erie Wastewater Management Study, Methodology Report," Buffalo, New York, March 1979.

(11) Melfi, D. A. and F. H. Verhoff, "Material Transport in River Systems During Storm Events by Water Routing," Lake Erie Wastewater Management Study Technical Report, U. S. Army Corps of Engineers, Buffalo, New York, March 1979.

(12) Treunert, E., A. Wilhelms, and H. Bernhardt, "Effect of the Sampling Frequency on the Determination of the Annual Phosphorus Load of Average Streams," Hydrochem. hyd. geol. Mitt, Vol. I, pp. 175-198, March 1974.

(13) Hetling, L. J., G. A. Carlson, and J. A. Bloomfield, "Estimation of the Optimal Sampling Interval in Assessing Water Quality of Streams," Environmental Modeling and Simulation, EPA 600/9-76-016, pp. 579-582, July 1976.

(14) Verhoff, F. H., S. M. Yaksich, and D. A. Melfi, "River Nutrient and Chemical Transport Estimation," ASCE, Journal of the Environmental Engineering Division, June 1980.

BIOAVAILABILITY OF PHOSPHORUS SOURCES TO LAKES

by

Terry J. Logan*

---

* Associate Professor, Agronomy Department, The Ohio State University, Columbus, Ohio

The role of phosphorus in accelerated eutrophication of Lake Erie and other areas in the Great Lakes drainage basin has been recognized and documented in recent years. Studies by LEWMS and PLUARG have shown that a major part of the total phosphorus load entering the lakes from tributary drainage is in the form of particulate P, and lake shoreline erosion also contributes large amounts of P. While it is readily accepted that soluble inorganic P in drainage water is available to algae and other aquatic vegetation, the bioavailability of sediment-bound phosphate is largely unknown. As a result, one is faced with two extreme scenarios: a) only the soluble inorganic P is bioavailable or b) all sources of P including sediment P are available. The first scenario is supported by the findings in New York where soluble inorganic P was shown to be the dominant form of stream-transported phosphate in stimulating growth of algae (Porter, 1975). On the other hand, Golterman (1977) found that sediment P in shallow polder lakes in Holland would maintain highly eutrophic conditions even if all external P sources were removed. Recent work by Allan and Williams (1978) demonstrated the importance of biologically available sediment P in fairly shallow Canadian prairie lakes.

The importance of sediment as a source of P for algae is governed by a number of factors. Streams which carry a low sediment load, and/or sediment of coarse-texture and stream-bank origin will have much of their biologically available P as soluble inorganic P as a consequence of the lower P content of coarse sediment (Williams _et al_, 1976 a). Consideration must also be given to physical lake dynamics. Stream sediments which settle rapidly into deep lakes will only be _positionally_ available to algae in the photic zone for short periods as in the central and eastern basins of Lake Erie, thereby minimizing the significance of sediment P as a source of biologically available phosphorus. In contrast, we have the situation where streams carry a high load of fine-grained sediment into shallow lakes, a situation similar to that in the western basin of Lake Erie. In this instance, factors which serve to increase the importance of sediment P are: the high percentage of the total phosphorus load as sediment P, the higher content of P in clay-sized sediment, and the longer period that this suspended sediment load is positionally available to algae in the photic zone.

Procedures to estimate bioavailability of sediment P from tributary sources must take into account the conditions under which algae obtain P from sediment. Algae can derive some P from sediment in the photic zone for short periods and under aerobic conditions. In addition, available P is derived from bottom sediments during anoxic regeneration and subsequent lake inversion, a markedly different chemical environment than exists in the photic zone. While much of the P regeneration is from decomposed algal biomass, sediment P is also released under anoxic conditions. As a result of this dichotomy, bioavailable sediment P will be viewed here in two ways: a) positionally available, to represent short-term release of P to algae in surface waters, and b) total potentially available, to represent maximum P which can be released over time by all mechanisms. Procedures to estimate sediment P bioavailability will be discussed in the context of this concept.

In this paper, I will discuss the bioassay procedures used to measure available P, the studies which correlated biological availability with chemical extraction, estimates of bioavailability of Great Lakes sediments and waters, and interpretations of these findings for point and nonpoint source P management.

BIOASSAY MEASUREMENT OF AVAILABLE P

Recent bioassays of the availability of sediment P for uptake by aquatic plants have simply involved culturing algae in a suspension of river or lake sediments, in which the sediment P is the only possible phosphorus source and other necessary nutrients are in excess supply. Following an incubation period either the algal phosphorus content or the algal biomass (employing a P/biomass conversion factor) is used to estimate the amount of phosphorus that had become available.

Cowen and Lee (1976a) employed the test alga Selenastrum capricornutum to measure the available P in the particulate P portion of urban runoff samples collected in Madison, Wisconsin. After 19-22 day incubation of the Selenastrum in assay flasks containing AAP medium minus P and runoff particulate P, they compared the cell counts obtained to a standard curve of 18 day cell counts versus initial orthophosphate concentration. In this way they converted cell counts to available P. This availability was most closely approximated by the NaOH-extractable fraction, while exchangeable P (anion exchange resin extractable) slightly underestimated the algal available fraction.

Cowen and Lee (1976a, b) applied the same procedure described above to the assessment of available P in sediment carried by tributaries to Lake Ontario (Niagara, Genesee, Oswego, and Black Rivers). They found that 6 percent or less of the particulate P was available based on growth of Selenastrum. In this case the algal available P was not consistent with NaOH-extractable P (mean, 17-25% of inorganic particulate P; range, 11-28%) or resin-extractable P (mean, 17-25%; range 6-31%). The relatively low availability was, however, consistent with the findings of Logan et al (1979) on four New York streams and Porter (1975) in Fall Creek, a small New York watershed emptying into Cayauga Lake.

Sagher et al (1975) determined NaOH-extractable P in Wisconsin lake sediments before and after algal incubation and found that 0.1 N NaOH extractable P at wide extraction to sediment ratios (> 500:1) was highly correlated with the P utilized by algae. This agreed with the findings of Cowen and Lee (1976a, b) who also had a good correlation between NaOH extractable P and P bioavailability.

Dorich and Nelson (1978) measured availabiltiy of sediment-bound P in Black Creek by culturing algae for two weeks in synthetic medium with gamma radiation sterilized sediments as the only P source, and determining the quantity and chemical extractability of particulate P in the flask before and after incubation. By performing the same procedure for sediment-free algae culture (containing 0.2 mg/ℓ as soluble orthophosphate), the extractability of the algal P was analyzed and the results were used to correct the values obtained from the sediment-algal system extractions. From the chemical extraction data, they surmised that most of the algal available P was from the Al- and Fe-bound inorganic fractions. They used NH_4F followed by NaOH extraction, but I believe that the sum of these two extractions are approximately equal to a single NaOH extraction and, therefore, their data support the availability of NaOH extractable P found by Sagher et al (1975) and Cowen and Lee (1976a, b).

In a recent study Verhoff et al (1978) attempted to determine the rate at which an indigenous phytoplankton population could utilize phosphorus from Lake Erie tributary waters. The procedure involved incubation of the algae with the river sediments and periodic harvest of the biological solids. A mass balance performed on total phosphorus and total inorganic solids allowed the calculation of the rate of conversion to available P. In contrast to studies on lake suspended material and lake bottom muds, the rate of algal immobilization of available P from the river sediments was quite low. The conclusion was that a linear availability rate of between 0.2 - 0.4%P/day could be expected. This slow rate of release over long time periods suggests that the rate of P release is more important than the ultimate availability.

CHEMICAL EXTRACTION OF SEDIMENT PHOSPHORUS

The only true measure of algal available phosphorus is a biological assay which determines the amount of phosphorus that an algal community can withdraw from the sample. Since bioassays are often tedious and more variable than chemical methods, however, it would be quite advantageous to relate the biologically determined available P to some fraction of the sediment P as measured by chemical extraction.

There is a growing body of research on chemical extraction procedures to estimate bioavailable sediment P. Much of the early work was done on soils, with more recent studies on lake and stream sediments. Differences in these studies can be attributed, in part, to differences in the bio-ogical and physicochemical characteristics of soils and sediments. A major treatment of the subject is not intended here. However, several major differences between soils and sediments are apparent. First, because of their fluvial transport, sediments are unstructured and generally more fine-grained than the soils from which they were derived. They tend to be enriched in organic matter, and this together with their fine-grained nature results in an enrichment of sediments with phosphate, hydrous oxides of iron and some aluminum and, in some sediments, with carbonates. Suspended stream sediments behave much like their soil precursors except for their P enrichment (Green _et al_, 1978). Bottom sediments, on the other hand, in both lakes and streams may be subjected to long periods of anoxia with subsequent reduction and solubilization of iron (Patrick and Mahapatra, 1968). Phosphate release from suspended sediments is much more similar to that from soil than from bottom sediments. Discussion of chemical extraction of sediment P must consider these significant differences.

Workers at Wisconsin (Chang and Jackson, 1957) began to look at sequential chemical extraction to characterize soil P. Their original theory was that phosphorus in soil occurred as discrete chemical forms which could be selectively removed by sequential chemical extraction. This theory of discrete P forms in soil has been questioned by Bache (1963, 1964), Bauwin and Tyner (1957) and others. A more prevalent view today is that much of the inorganic P in soil is chemisorbed to a number of reactive surfaces including iron and aluminum oxides and hydrous oxides, amorphous alumino-silicates and carbonates, or occluded in the matrices of a number of soil mineral forms.

Major developments in the basic scheme proposed by Chang and Jackson

(1957) have been accomplished by Williams and Walker (1969 a and b); Williams et al (1971 a, b); Allan and Williams (1978) for soils and lake sediments.

In recent years, Williams (Williams et al, 1976 a, b; Allan and Williams, 1978) has simplified the scheme for lake sediments even further. He proposed two inorganic sediment-P fractions: non-apatite inorganic phosphorus (NAIP) extracted by citrate-dithionite-bicarbonate (CDB), and apatite-P extracted by HCl or H_2SO_4. Allan and Williams (1978) have proposed that the NAIP fraction be considered bioavailable, based on correlation of CDB extraction with the NTA extraction of Golterman (1976) which was found to estimate sediment P availability of Scenedesmus. Armstrong et al (1979) have recently used NaOH with dilute sediment suspensions to extract NAIP. These procedures and others are summarized in Table 1.

In order to obtain a true assessment of algal availability the method must make use of the algae themselves as an indicator of the quantity and P should be defined as that quantity actually taken up by the algae, rather than the growth response under test conditions. It is therefore recommended that an assessment methodology actually measure the amount of P incorporated into the biomass of the test organism.

On the other hand, a chemical assessment technique is desirable from the standpoint of relative ease and quickness of obtaining results. These are very important attributes if one is attempting to evaluate all the tributary sources to one of the Great Lakes, for example. It is therefore necessary for future research to place equal emphasis on both chemical and biological approaches to assessing P availability. Even more important is the need for future work to attempt to correlate the quantity and the rate of production of biologically measured available P with the chemical tests. In other words, every attempt should be made to find an operationally defined chemical extraction which best estimates algal available phosphorus.

The previous discussion indicates that there are two independent approaches to measurement of sediment bioavailability:

1. Incubation with algae and correlation of algal uptake with chemical or resin extraction (Golterman, 1976; Sagher et al, 1975; Cowen and Lee, 1976 a, b; Dorich and Nelson, 1978) which showed that NaOH was a good measure of algal available sediment P.

2. Chemical extraction (fractionation) of soil and sediment phosphorus with the underlying assumption that some "forms" of particulate P are more available to algae than others (Williams et al, 1976b). These assumptions were based on studies which showed a low availability of apatite phosphate (Golterman et al, 1969) on the one hand, and others which indicated that, terrestrial plants (crops) at least, got their "available" P from inorganic forms associated with iron and aluminum minerals (Robertson et al, 1966).

The concepts developed by these two approaches have been combined or used singly to determine algal bioavailability of particulate P. They all assume that non-apatite inorganic P (NAIP) is available over time and several methods are given for NAIP measurement (Table 1). Cowen and Lee (1976 b) considered resin extractable P to be short-term available

Table 1. Summary of phosphorus forms, their biological availability and methods for their analysis.

Phosphorus Fractions and Forms	Bioavailability	Methods of Analysis	References
		Dissolved Phosphorus	
Dissolved reactive P (DRP): $H_2PO_4^-$ and $HPO_4^=$	Directly available	Orthophosphate in filtrate*	Standard Methods (1975)
Dissolved condensed P(DCP): P-O-P bonds	Converted to DRP through fairly rapid hydrolysis	Orthophosphate analysis following acid hydrolysis of filtrate*	Standard Methods (1975)
Dissolved organic P (DOP): bonds	Converted to DRP through biological mineralization; usually slow except for "fresh" plant tissue extracts and human and animal wastes	Difference between total dissolved P and sum of DRP and DCP in filtrate*	Standard Methods (1975)
		Particulate Phosphorus	
Inorganic P Non-Apatite Inorganic P (NAIP): P adsorbed on metal hydrous oxides (Fe, Al) Fe-and Al-P minerals, Ca-P (non-apatite)	Available through dissolution or desorption of phosphate when DRP concentration is low due to dilution, biological uptake or chemical immobilization	NAIP has been extracted from particulate material with: NaOH (dilute sediment suspensions) citrate-dithionite-bicarbonate (CDB) CDB/NaOH (sequential) NaOH/CDB (sequential) Anion resin Aluminum Resin	Williams et al (1980) Williams et al (1976a) Williams et al (1976b) Logan et al (1980) Cowen and Lee (1976) Huettl et al (1979)
Apatite	Essentially unavailable because of slow dissolution of apatites	HCl extraction following NAIP extraction	Williams et al (1976a)
Organic P Nucleic acids, phospholipids, inositol phosphates, others	Converted to DRP through biological mineralization; may be rapid for substantial fraction of fresh plant tissue or human and animal wastes; slow for soil and sediment organic P	Difference between total particulate P and inorganic particulate P	Sommers et al (1972)
Condensed P	Released from plant tissues at senescence and hydrolyzed to DRP. Small fraction compared to organic P	Usually included as organic P unless hydrolysis is rapid and would then be extracted as NAIP	--

*Dissolved phosphate is defined as that P which is not retained by a 0.45μ dia. filter (Standard Methods, 1975).

with NaOH-P available over a long period of time (unspecified). Logan et al (1979) assumed that NaOH-P (at an extractant/sediment ratio of 50:1 rather than the wider ratios used by others) represented P that could be extracted by algae in the photic zone of lakes under aerobic conditions, while the subsequent CDB extraction reflected P that might become available under the reducing conditions found in the anoxic hypolimnion of stratified lakes. These views should be considered when reviewing the bioavailability data in the next section.

BIOAVAILABILITY OF SEDIMENT PHOSPHORUS

A large part of the research on sediment bioavailability has been done on Great Lakes Basin soils and sediments and are, therefore, very pertinent to this discussion.

Sagher et al (1975) used bioassay and NaOH extraction to measure bioavailability of Wisconsin lake sediments and found that 60 to 95% of the sediment inorganic P (Pi) of noncalcareous and 60 to 85% of the Pi of calcareous sediments were available.

Cowen and Lee (1976 a, b) used bioassay with resin and NaOH extraction to estimate bioavailability of urban storm runoff and tributary sediments. Resin and NaOH extraction of Madison, Wisconsin urban runoff sediments gave mean values of 22-27% of total particulate phosphorus (TPP) and 13-17% TPP, respectively. Similar samples from Genesee River, N.Y. urban runoff gave mean values of 18-30% of TPP and 11-25% TPP for NaOH and resin extraction. Cowen and Lee (1976 b) also sampled tributaries to Lake Ontario and found NaOH and resin extractable values of 13-18% TPP and 6-17% TPP for samples taken at the mouth of the Genesee River. NaOH and resin extraction percentages of TPP were similar for urban and rural sediments and were somewhat higher for Wisconsin than New York sediments. Lee et al (1980) have recently proposed that a value of 20% of TPP is a reasonable estimate of bioavailability of Great Lakes tributary sediments.

Logan et al (1979) used sequential extraction with NaOH and CDB to estimate bioavailability of 66 suspended sediment samples from 36 tributaries in the Lake Erie drainage basin. A summary of their data expressed as percentage of Pi is given in Table 2. Their data showed that New York tributaries had lower bioavailability than those from Michigan and Ohio, a finding similar to that of Cowen and Lee (1976 b). They attributed this difference to greater stream-bank erosion and coarser-grain nature of the New York samples.

Armstrong et al (1979) used resin and NaOH extraction to estimate the availability of stream sediments in five tributaries to the Great Lakes; they also studied recessional shoreline soils. Resin P ranged from 7-19% of TPP for the tributary samples and NaOH-P was 14-37% of TPP. Recessional soil samples were 2-10% of TPP and 1-10% of TPP for resin and NaOH extractions, respectively. Armstrong et al (1979) also extracted individual particle size fractions and found that there were slightly higher values for resin-P and NaOH-P in the clay fraction expressed as percent of TPP.

Dorich and Nelson (1978) used algal bioassay and NH_4F and NaOH sequential

Table 2. Percent Bioavailability of Sediment-P* as Estimated by Sequential Chemical Extraction with NaOH and CDB (Logan *et al*, 1979).

	NaOH-P	CDB-P	(NaOH + CDB)-P
Michigan	30.0	45.0	75.0
Western Ohio	41.9	35.9	77.8
Eastern Ohio	32.8	55.8	88.6
New York	14.0	28.5	42.5

* Expressed as percent of total sediment inorganic phosphorus.

extraction to analyze stream sediments from Black Creek in northeastern Indiana, an agricultural watershed. They found that about 20% of the TPP was available with somewhat higher values for the Maumee River at the junction with Black Creek.

Finally, Thomas (unpublished) reported that samples from Canadian tributaries to the Great Lakes contained about 20-40% of TPP as NAIP, which Williams *et al* (1976 b) consider to be available in the long term.

Considering these data collectively, it would appear that the value of 20% of TPP proposed by Lee *et al* (1980) is not unreasonable for Great Lakes sediments, with a range of 10-50%. Sediments from tributaries draining into the eastern basin of Lake Erie (Logan *et al*, 1979) and Lake Ontario (Cowen and Lee, 1976 b) appear to have lower availabilities than those from the Corn Belt region.

AVAILABILITY OF OTHER PHOSPHORUS SOURCES

Precipitation Phosphorus

Lee *et al* (1980) reviewed the literature on P in precipitation. There was only one study (Cowen and Lee, 1976 b) which used bioassay to study availability of precipitation P, and it showed that <10% of the total P in Madison, Wisconsin snow samples were bioavailable. The great majority of precipitation studies showed that ~50% of the total P is soluble inorganic P although the values can range from 7-100%. Assuming that soluble inorganic P is 100% available (an assumption that may not be true, as discussed in the next section) then about 50% of precipitation phosphate is available.

Soluble Phosphorus

Several investigators (Rigler 1966, 1968; Lean 1963 a, b; Dorich and Nelson 1978) have found that soluble inorganic P (SIP) is not 100% available, while Walton and Lee (1972) found that SIP was essentially all available using standard bioassay procedures. The problem lies in the analytical method used to measure SIP. This is usually done by filtering the sample through 0.45 μ pore diameter membrane filters and analyzing the filtrate as reduced phosphomolybdate. As Lee *et al* (1980) have pointed out, the acid molybdate may react with arsenic or colloidal material containing P and overestimate the true SIP. This is especially of concern with the low

SIP concentrations normally found in lakes, but the error is much lower for the concentrations found in tributaries or wastewater discharges and these values can probably be considered to be 100% available.

THE IMPACT OF BIOAVAILABILITY OF P SOURCES ON A MANAGEMENT STRATEGY FOR THE GREAT LAKES

The Lake Erie Management Study in their Phase II Methodology Report (1979) estimated through Universal Soil Loss Equation (USLE) analysis that a maximum adoption of conservation tillage practices by basin farmers on suitable soils could reduce soil loss in the basin by ∿ 70%. A recent review of conservation tillage research studies by Logan (1980) has shown that conservation tillage is only 90% as effective in reducing total particulate phosphorus (TPP) loads as in reducing soil loss. That is, if soil loss is reduced 70% by conservation tillage, TPP will be reduced by 63%. Logan (1980) also showed that conservation tillage increased or had little effect on soluble P loads. The Lake Erie Management Study (1979) showed that, if point source phosphorus discharges to Lake Erie are reduced by achieving a 1.0 mgP/l effluent standard, this maximum adoption of conservation tillage would almost achieve the target annual load of 11,000 metric tons of P considered necessary to eliminate anoxia in the Central Basin of the lake. Table 3 gives the various sources of P entering the lake before and after adopting conservation tillage in terms of total P and available P. The point source loads remaining after reduction to the 1.0 mgP/l effluent standard is separated into those loads which are discharged directly into the lake (e.g. Toledo, Cleveland, etc.) and those which discharge into Lake Erie Basin tributaries (e.g. Fort Wayne, Defiance, etc.). The direct discharge effluent P is assumed to be 75% available based on the bioassay work of DePinto et al (1980), while the tributary point sources are assumed to be so mixed with the tributary water and sediment that they have the same availability as rural diffuse loads (Table 3). The rural diffuse load is assumed to be 80% particulate and 20% soluble as shown by tributary monitoring, and the soluble load is assumed to be 100% available. The particulate rural diffuse load is assumed to be 20 and 40% available, a range found by Logan et al (1979) for Lake Erie tributary suspended sediments. The urban diffuse loads, the upper lakes loads and the tributary point source loads are all assumed to be 80% particulate and 20% soluble, with the soluble load 100% available and the particulate P 30% available (mean of the 20 and 40% values for rural diffuse particulate P.)

Table 3 shows that conservation tillage would reduce the total P load to 11,404 metric tons, close to the target load of 11,000 tons, a 26.5% reduction. In terms of available P, however, the reduction is only 9.7 to 16.6%, depending on the percent availability assumed for particulate P. The data (Table 3) also show that the residual direct point source load and the soluble rural diffuse load contribute a major portion of the available P load before or after adoption of conservation tillage.

Present lake models (Bierman, 1980) do not adequately account for varying availability of P sources, and therefore, there is no way to determine an available P target load for Lake Erie or other Great Lakes. However, it is obvious that response of algae to soluble P must be different than to

Table 3. Total and available phosphorus loads (metric tons) to Lake Erie before and after adoption of conservation tillage practices.

	Upper Lakes[a]	Point f		Atmospheric[e]	Rural Diffuse			Urban[a] Diffuse	Total Load	
		Direct[b]	Tributary[a]		Particulate[c] 20%	40%	Soluble		20%	40%
Total P										
Before	1080	2455	617	1119	6610	6610	1530	1570	15518	15518
After	1080	2455	617	1119	2496	2496	1530	1570	11404 (26.5%)[d]	11404 (26.5%)[d]
							Objective = 11,000			
Available P										
Before	475	1841	272	560	1132	2264	1530	691	6501	7633
After	475	1841	272	560	499	998	1530	691	5868 (9.7%)[d]	6367 (16.6%)[d]
							Objective = ?			

---

[a] Assumption: 80% of the total load is particulate and 30% of the particulate load is available; 100% of the soluble load is assumed to be available.

[b] Assumption: direct discharge of sewage effluent to the lake is 75% available (DePinto *et al*, 1980).

[c] Assumption: short term availability of rural diffuse sediment P is 20% and long term availability is 40% (Logan *et al*, 1979).

[d] Percent reduction with conservation tillage.

[e] Atmospheric P sources are assumed to be 50% available.

[f] Residual point sources after reduction to 1 mgP/l.

particulate P sources which may settle out of the photic zone before they can be completely utilized. Phosphorus control strategies for deep lakes with little sediment resuspension or lake overturn must emphasize soluble P sources more than for shallower lakes where sediments are continuously resuspended and lake overturn can bring to the surface P released from bottom sediments. If the emphasis is to be placed equally on sediment as well as soluble P sources (e.g. for Western and Central Lake Erie) then erosion control by conservation tillage merits equal consideration with point source reduction. If, however, soluble P loads are the most important, then control of direct point sources should receive the most attention. In addition, agricultural practices which control soluble P losses would need to be emphasized. These would include fertilizer management (Oloya and Logan, 1980) and livestock waste management (Porter, 1975).

Excluded from the phosphorus input list in Table 3 is phosphorus contributed from shoreline erosion. The total P load from shoreline erosion is more than half of the entire P load to Lake Erie from all other sources (Thomas _et_ _al_, 1980), but shoreline sediments have an availability < 5%. While even a low availability of 5% still gives a large available P load, its impact is likely to be in the near-shore zone and not in the mid-lake area for which the target loads were developed.

CONCLUSIONS

Phosphorus exists in soluble and particulate forms, and research has shown that these forms vary in availability to algae from a low of 5% or less for subsoil materials (detached and transported during streambank erosion and lake shoreline erosion) to essentially 100% available for soluble (dissolved) inorganic P.

Phosphate availability has been determined by algae biassay as well as chemical extraction techniques, and depending on the method used, may reflect total availability or short-term availability. While these methods all measure the _capacity_ of sediment to release P to algae, few studies have investigated the _rate_ at which sediment-P is made available. A knowledge of P release kinetics is important in determining the _positional_ availability of P from sediments which enter lakes and are subjected to varying rates of settling and resuspension.

Phosphorus management strategies must consider the bioavailability of the various P sources as well as the positional availability of particulate P as determined by the sedimentation and resuspension characteristics of the receiving lake. Deep lakes will respond more to control of soluble P sources than to sediment-P control, while in shallow lakes, algae may obtain a large percentage of bioavailable P from sediments, and control of sediment loads by controlling erosion on basin soils might be more effective.

REFERENCES

1. Allan, R.J. and J.D.H. Williams. 1978. Trophic status related to sediment chemistry of Canadian Prairie Lakes. J. Environ. Qual. 7: 99-106.

2. Armstrong, D.E., J.R. Perry, and D. Flatness. 1979. Availability of pollutants associated with suspended or settled river sediments, which gain access to the Great Lakes. Final Report. Wisconsin Water Resources Center, Madison.

3. Bache. B. W. 1963. Aluminum and iron phosphate studies relating to soils: 1. Soil Sci. 14:113-123.

4. Bache, B.W. 1964. Aluminum and iron phosphate studies relating to soils: 2. Soil Sci. 15:110-116.

5. Bauwin, G.R. and E.H. Tyner. 1957. The nature of reductant soluble phosphorus in soils and soil concretions. Soil Sci. Soc. Amer. Proc. 21:250-257.

6. Bierman, V.J. 1980. A comparison of models developed for phosphorus management in the Great Lakes. In Phosphorus Management strategies for Lakes. R. C. Loehr, C. S. Martin, W. Rast, Eds. Ann Arbor Science.

7. Chang, S.C. and M.L. Jackson. 1957. Fractionation of soil phosphorus. Soil Sci. 84:133-134.

8. Corps of Engineers, Buffalo District. 1979. Lake Erie Management Study Methodology Report. Buffalo, N.Y. 146 pages.

9. Cowen, W.F. and G.F. Lee. 1976a. Algal nutrient availability and limitation in Lake Ontario tributary waters. Ecological Research Series. EPA-600/3-76-094a.

10. Cowen, W.F. and G.F. Lee. 1976b. Phosphorus availability in particulate materials transported by urban runoff. J. WPCF. 48:580-591.

12. Dorich, R.A. and D.W. Nelson. 1978. Algal availability of soluble and sediment phosphorus in drainage water of the Black Creek watershed. Unpublished report. Purdue Agric. Exp. Sta.

13. Golterman, H.L. 1976. Sediments as a source of phosphorus for algae growth. In H. L. Golterman (Ed.) Interactions between sediments and freshwater. Proc. 51L-UNESCO Conf. Junk and Pudoc, The Hague, Netherlands.

14. Golterman, H.L. 1977. Forms and sediment associations of nutrients, pesticides and metals. Nutrients-P. In Proc. Workshop on Fluvial Transport of Sediment-associated Nutrients and Contaminants. H. Shear, Ed. IJC-PLUARG, Windsor, Ontario.

15. Golterman, H.L., C.C. Bakels and J. Jakobs-Mogelin. 1969. Availability of mud phosophates for growth of algae. Verh. Int. Verein. Limnol. 17:467-479.

16. Green, D.B., T.J. Logan and N.E. Smeck. 1978. Phosphate adsorption-desorption characteristics of suspended sediments in the Maumee River Basin of Ohio. J. Environ. Qual. 7:208-212.

17. Huettl, P.J., R.C. Wendt and R.B. Corey. 1979. Prediction of algal-available phosphorus in runoff suspensions. J. Environ. Qual. 8:130-132.

18. Lean, D.R.S. 1973a. Phosphorus dynamics in lake water. Science 179: 678-679.

19. Lean, D.R.S. 1973b. Movements of phosphorus between its biologically important forms in freshwater. J. Fish Res. Board Can. 30:1525-1536.

20. Lee, G.F., R.A. Jones and W. Rast. 1980. Availability of phosphorus to phytoplankton and its implications for phosphorus management strategies. In Phosphorus Mangement Strategies for Lakes. R. C. Loehr, C.S. Martin, W. Rast. Eds. Ann Arbor Science.

21. Logan, T.J. 1978. Available phosphorus levels in Lake Erie Basin soils. LEWMS Final Technical Report. Corps of Engineers, Buffalo District, Buffalo, N.Y.

22. Logan, T. J. 1980. The effects of conservation tillage on phosphate transport from agricultural land. Lake Erie Management Study. Technical Report Series. Corps of Engineers, Buffalo District, Buffalo, N.Y.

23. Logan, T.J., T.O. Oloya and S.M. Yaksich. 1979. Phosphate characteristics and bioavailability of suspended sediments from streams draining into Lake Erie. J. Great Lakes Res. 5:112-123.

24. Oloya, T. O. and T. J. Logan. 1980. Phosphate desorption from soils and sediments with varying levels of extractable phosphate. J. Environ. Qual. 9:526-531.

25. Patrick, W.H. and I.C. Mahapatra. 1978. Transformation and availability of nitrogen and phosphorus in waterlogged soils. Advan. Agron. 20:323-359.

26. Porter, K.S. 1975. Nitrogen and phosphorus, food production, waste and the environment. Ann Arbor Science, Ann Arbor, Mich. 372 pages.

27. Rigler, F.H. 1966. Radiobiological analysis of inorganic phosphorus in lake water. Tech. Internat. Verein. Limnol. 16:456-470.

28. Rigler, F.H. 1968. Further observations inconsistent with the hypothesis that the molybdenum blue method measures orthophosphate in late waters. Limnol Oceanogr. 13:7-13.

29. Robertson, W.K., L.G. Thompson, Jr. and C.E. Hutton. 1966. Availability and fractionation of residual P in soils high in aluminum and iron. Soil Sci. Soc. Amer. Proc. 30:446-451.

30. Sagher, A., R.F. Harris, and D.E. Armstrong. 1975. Availability of sediment phosphorus to microorganisms. Univ. of Wisconsin Water Res. Cent. Tech. Report WIC WRC 75-01. Wisconsin.

31. Sommers, L.E., R.F. Harris, J.D.L. Williams, D.E. Armstrong and J.K. Syers. 1970. Determination of total organic phosphorus in lake sediments. Limnol. Oceanog. 15:301-304.

32. Standard methods for the examination of water and wastewater. 13th Ed. 1975. American Public Health Assoc. Washington, D.C.

34. Verhoff, F.H., M. Heffner and W.A. Sack. 1978. Measurement of availability rate for total phosphorus from river waters. Final Report. LEWMS, Corps of Engineers, Buffalo, N.Y.

35. Walton, C.P. and G.F. Lee. 1972. A biological evaluation of the molybdenum blue method for orthophosphate analysis. Tech. Internat. Verein. Limnol. 18:676-684.

36. Williams, J.D.H. J.K. Syers, and T.W. Walker. 1967. Fractionation of soil inorganic phosphate by a modification of Chang and Jackson's procedure. Soil Sci. Amer. Proc. 31:736-739.

37. Williams, J.D.H., J.M. Jaquet and R.L. Thomas. 1976a. Forms of phosphorus in surficial sediments of Lake Erie. J. Fish. Res. Board Can. 33:413-429.

38. Williams, J.D.H., T.P. Murphy and T. Mayer. 1976b. Rates of accumulation of phosphorus forms in Lake Erie sediments. J. Fish. Res. Board Can. 33:430-439.

39. Williams, J.D.H., J.K. Syers, R.F. Harris, and D.E. Armstrong. 1971a. Fractionation of inorganic phosphate in calcareous lake sediments. Soil Sci. Soc. Amer. Proc. 35:250-255.

40. Williams, J.D.H., J.K. Syers, D.E. Armstrong, and R.F. Harris. 1971b. Characterization of inorganic phosphate in noncalcareous lake sediment. Soil Sci. Soc. Amer. Proc. 35:556-561.

41. Williams, J.D.H. nad T.W. Walker. 1969a. Fractionation of phosphate in a maturity sequence of New Zealand basaltic soil profiles: 1. Soil Sci. 107:22-30.

42. Williams, J.D.H. and T.W. Walker. 1969b. Fractionation of phosphate in a maturity sequence of New Zealand basaltic soil profiles: 2. Soil Sci. 107:213-219.

WATER MONITORING PROGRAM - PLANNING FOR 1981

WILLIAM H. SANDERS III

DIRECTOR S&A DIVISION REGION V

Regardless of the control program we are attempting to implement, the underlying question is to what extent does a remedial program--be it AWT/AST treatment facilitis, best management practices for NPDS control, etc.--the question remains: to what extent does the program correct the problem by resulting in improved water quality. That is a basic question to ask, yet a most complex and difficult one to answer. All of the programs you have heard about and discussed at this seminar are focused upon that ultimate objective of improving water quality. Yet we have found that our tools for assessing changes in water quality, particularly in being able to definitively associate those changes with remedial programs, have been lacking. It is in order to fill that informational void that the agency is redefining and refining, our water monitoring programs.

Develoment of the Region V Monitoring Planning for 1981 is based on recognition of the re-newed emphasis on the human health aspects of water pollution control. The driving force behind this concern for protection of health is the awareness of the scope and potential hazard of the toxic wastes entering the nations's waters through industrial processess, materials handling and waste disposal. Because of the large number of sources of all description concentrated in Region V, the problem of identifying and quantifying the impact of toxic and hazardous wastes is of particular concern. We have recently begun an assessment of the adequacy of the existing monitoring networks and programs to provide a data base for use in identifying problem areas throughout the Region.

While the importance of the control of toxic and hazardous wastes cannot be overemphasized, it is also intended to maintain the capability to assess water quality for the more traditional pollutants. For this reason, the assessment of existing monitoring against current needs is best made with repect to the basic program as described in the "Basic Water Monitoring Program", U.S. EPA Standing Work Group on Water Monitoring, (EPA 440/9-76-025, 1977).

Given the adequacy of the basic program and the availability of resources, a re-definition of the Federal and State activities may be necessary to monitor water quality, particularly to ensure that the Region waters are free of the more harmful health related pollutants.

2. HIGHLIGHTS FROM THE REVIEW

From the assessments of the state programs, it is obvious that the strategy envisioned in the Basic Water Monitoring Program has not had complete acceptance. As a result, the program has had only marginal success in developing a data base useful for managers in carrying out pollution control programs. An important element integral to the strategy in the basic program is the need to enter monitoring data into STORET. The usefulness of the data is dependent on its availability to users at all levels. However, the only parameter in STORET in sufficent quantities for comparative analysis was dissolved oxygen. An even more glaring omission is the paucity of information related to toxics which is available for use.

Based on state acceptance in their own programs, most parts of the basic program are considered viable and should be retained. However, several parts of the program have had little or no state support.

Portions of the ambient monitoring program have received wide acceptance, primarily because the National Ambient Monitoring Stations are a subset of existing state ambient networks. These are fixed stations intended to provide trend information. However each state has a much larger ambient network designed to gather trend data that is not covered by the basic network and to provide a measure of the effectiveness of pollution abatement programs. The latter may not be the best use of fixed station monitoring.

Intensive surveys should be used for multiple purposes rather than to support a single program. They should be used in identifying or quantifying problems related to toxics and NPDES permitting, waste load allocation and stream model development and verification. However, resources are not available to routinely carry out all of these surveys. This is particularly true for toxics. Efforts spent on fixed station monitoring competes for resources which may be better spent on intensive surveys. The ambient program will be reviewed jointly with the state agencies, with the intent to free-up more resources for intensive survey purposes.

The toxic monitoring needs which are surfacing at the present time far outstrip the toxic portion of the basic program. Recognizing that the basic program was introduced in 1977, and reflects the known need for toxics data at that time. That need is minimal when compared to current needs. Since most of the states have been unable to meet the basic requirements, the program requires significant restructuring accompanied by a large shift in resources and initial capital investment, particularly to develop laboratory capabilities.

By including toxic monitoring in the ambient program as described in the basic document, trend data will be developed over time. Of more immediate need, toxic monitoring should be made part of intensive surveys conducted near known or suspectd dischargers in support of the permitting program. As in the ambient monitoring, fish will be used as the sample medium. The use of fish is chosen as the best indicator of stream quality since they are an excellent bio-accumulator of toxic pollutants. The analysis of fish tissue shall be broad scan and include the parameters listed in the basic document.

Having discussed several of the issues we found in assessing existing state monitoring programs, I now move to brief highlights of a strategy under active consideration for the next five years that will accommondate non-point sources as well as point sources of pollution.

3. WATER MONITORING STRATEGY

It is the intent in Region V to oversee a water monitoring program which will provide program managers with a valid data base which is responsive to their needs. For the next five years, the most pressing concern is the protection of the public health through control of toxic and hazardous sources of pollution. This strategy is intended to enhance the data base for use in the important decisions on identificaiton and control of this type of pollution. It is also intended that the more traditional pollutants, those which have potenital adverse impact on public health, are not to be ignored. As a result, the Basic Water Monitoring Program provides the basis of this strategy. The components of the water monitoring program are: ambient monitoring (including toxic monitoring), effluent monitoring, intensive surveys, biological monitoring, quality assurance and STORET.

AMBIENT WATER MONITORING

The States should fully implement the basic water monitoring network, including sampling for fish tissue, sediment and water once yearly at all "core" stations. Where toxics are found in the fish tissue, bottom sediments should then be analyzed. If toxics are found in the sediment samples, water column samples should be analyzed for the toxic parameters. The States should make a thorough evaluation of their own ambient water monitoring stations to eliminate any duplication or any stations that are not vital to establishing trend data. All stations in excess of those needed for trend purposes should be discontinued. The intent of this re-evaluation is to reduce resource needs in this activity to devote more time to intensive surveys and toxic monitoring.

All States in Region V must develop full field and laboratory capabilities for toxic monitoring at all trend stations using fish as the sample medium. Fish tissue analysis shall be broad scan and include the priority pollutants. This capability will also be used to support the effluent monitoring (permitting program and intensive survey program).

EFFLUENT MONITORING

The States should concentrate their compliance monitoring efforts on the re-issuance of permits with special emphasis on the control of toxicants. Consistent with the basic monitoring program, all major dischargers shall be inspected annually to determine compliance status. Known toxic sources shall be first priority for compliance sampling; however, this in no way relieves the states of their responsibility to evaluate all majors.

INTENSIVE SURVEYS

The States should revise their monitoring strategy to reflect higher priority for the use of intensive surveys in such areas as toxic pollutants, water-quality limited streams and to determinne treatment levels to meet water quality standards. To assure that the objectives of the Section 106 and the basic water monitoring programs are met, more resources and emphasis should be devoted to intensive surveys as a means of verifying the usefulness of pollution control strategies.

BIOLOGICAL MONITORING

The proposed Biological Monitoring Program as described in the basic document shall be revised so that each state shall be required to implement biological studies as part of intensive surveys, where such surveys are conducted near known or suspected toxic sources.

QUALITY ASSURANCE

To assure the validity of the data generated through this water quality program, the quality assurance policy as established in Region V will be followed. The first priority in the Region V quality assurance policy is to establish and implement a plan to define and quantitate the end product-data quality. This includes all data generated by the Federal and State/local agencies. To ensure that this policy is carried out, all State/local agency quality assurance programs must be approved by the Region V, Quality Assurance Office. To facilitate this documentation, peer reviews of state plans shall be completed in the other Region V states. This review shall be coordinated by the Region V Quality Assurance Office.

STORET

The states should enter all ambient quality assured data into STORET within 90 days after sample collection and analysis. Additionally, the states should assess the ambient water quality data in the STORET system in order to determine ambient water quality conditions and trends. This assessment should be forwarded to EPA/State program managers in order to impact toxic source identification, Section 208 planning, wasteload allocations/intensive surveys and state EPA agreements. To improve STORET in Region V, use of data management and interpretation tools such as summaries and trends on a quarterly basis should be made Region policy. Routine use of these tools will result in an improved data file.

Finally, the intent of this effort will be to provide decision makers data of known precision and accuracy that will allow for an evaluation of program effectiveness. That is a tall order, but is key to our ability to making those critical decisions on which programs to focus upon in the future.

CONSERVATION TILLAGE PRACTICES TO CONTROL AGRICULTURAL POLLUTION

by

J. P. Crumrine and D. U. Wurm*

When shopping around for point and non-point source control measures, you soon find yourself asking questions as if you were shopping at a local supermarket. Which product or control measure does the best job, and what is the cost of each? In other words, how do I get the most for my money?

While the Honey Creek Watershed Project was not designed specifically to answer these questions, as a nonpoint source control demonstration program, it does provide valuable information regarding the effectiveness and implementation costs of control practices for a 96000 acre (38000 hectare) agricultural watershed in the Lake Erie Basin of north central Ohio.

The Honey Creek Project, now in its second year of a 3-year effort, is managed by local Soil and Water Conservation Districts, but funded by the U. S. Army Corps of Engineers as part of their Lake Erie Wastewater Management Study (1). Purpose of the Project is to see how farmers and local agricultural agency personnel respond to the need for improved water quality and to demonstrate "best management practices," that would contribute to improved Lake Erie water quality, particularly conservation tillage. It is through the implementation of conservation tillage practices (2), coupled with data from previous Army Corps studies (3) that we may gain insight as to how well the practices reduce erosion or phosphorus transport and practice costs.

CONSERVATION TILLAGE

First, what is conservation tillage? Soil Conservation Service in Ohio defines conservation tillage as a "method of working the land leaving crop residues on the surface to protect the soil from the erosive forces of wind and rain." (4) For the Honey Creek Project conservation tillage has been defined as any tillage system that leaves a minimum of 1000 pounds (454 kilograms) of previous crop residue on the soil surface at planting. The ultimate conservation tillage system is "no-till" where virtually all previous crop residue remains on the surface at planting, normally 4000 to 6000 pounds (1800 to 2700 kilograms) expressed as corn residue equivalent. Tillage systems incorporating a portion of previous crop residue but having more than 1000 pounds (454 kilograms) on the surface at planting time are described as "reduced" tillage systems. Table 1 gives a comparison of tillage systems based on the amount of previous crop residue left on the soil surface at planting, showing tillage operations that might typically occur in each.

---

*Project Manager and Project Conservationist, Honey Creek Watershed Project, Crawford, Huron, and Seneca Counties, Tiffin, Ohio

Table 1. Comparison of Tillage Systems by Amounts of Previous Crop Residue on Soil Surface at Planting and by Mechanical Operations That Might Typically Occur in Each.

	Conservation Tillage	
Conventional Tillage	Reduced Tillage	No-till
Spring fertilize	Spring fertilize	Spring fertilize
Plow	Chisel plow	Plant
Disk - 1	Disk	Spray - 1
Disk - 2	Plow	Spray - 2
Level	Spray	Combine
Plant	Combine	
Spray		
Cultivate - 1		
Cultivate - 2		
Combine		
0 to 1000 pounds (454 kg) residue at planting	1000 pounds plus (454 kg) residue at planting	

EROSION, PHOSPHORUS REDUCTIONS

With an idea now of what conservation tillage is, how well do the various practices work? Do they reduce erosion and phosphorus loss and if so by how much? For 10-15 acre (4-6 hectare) demonstration plots in the Honey Creek watershed, on those soils having yield responses to no-till equal to or greater than conventional tillage either naturally or with artificial drainage, soil loss estimates using the Universal Soil Loss Equation showed that reduced tillage systems on the average in 1979 decreased erosion rates from 7.1 to 4.5 T/Ac/Yr (16 to 10 MT/Ha/Yr) or 40 percent over the conventional fall plow system. On the same soils, but different fields, no-till decreased erosion rates from 6.9 to 1.4 T/Ac/Yr (16 to 3 MT/Ha/Yr) or 76 percent.

With respect to phosphorus yield reductions, the Lake Erie Wastewater Study Methodology report (3) assumes that application of conservation tillage practices will be from 60 to 90 percent effective in reducing phosphorus transport relative to reduction of erosion. These ranges of possible reductions are based on the fact that most phosphorus moves attached to the clay fraction of river sediment loads (5) (6), and that while reduced tillage practices may increase the proportion of clay sized particles in runoff, significant reductions in phosphorus transport can still occur (7) (8) (9).

For a relative effectiveness then of 75 percent, reduced tillage systems in the Honey Creek watershed would potentially decrease phosphorus transport from a present watershed condition rate of 0.84 Kg/Ha/Yr to 0.59 Kg/Ha/Yr or by 30 percent. No-till would decrease phosphorus transport from 0.84 to 0.36 Kg/Ha/Yr or by 57 percent.

Table 2. Average Effectiveness of Conservation Tillage Systems in Reducing Erosion Over Conventional Fall Plow System, T/Ac/Yr (MT/Ha/Yr), and Phosphorus Transport, Kg/Ha/Yr, for Demonstration Plots Within the Honey Creek Watershed.

EROSION REDUCTION

Conventional		Conservation Tillage					
Fall Plow		Reduced Tillage[a]			No-till		
T/Ac/Tr	(MT/Ha)	T/Ac/Yr	(MT/Ha)	% reduced	T/Ac/Yr	(MT/Ha)	% reduced
7.1	(16)	4.3	(10)	40			
6.9	(16)				1.4	(3)	76

PHOSPHORUS REDUCTION[b]

Kg/Ha/Yr	Kg/Ha/Yr	% reduced	Kg/Ha/Yr	% reduced
0.84	0.59	30	0.36	57

a. Chisel plow, disk field cultivate, etc.
b. At relative effectiveness of 75%.

COSTS OF IMPLEMENTING CONSERVATION TILLAGE IN A DEMONSTRATION PROJECT

Now that we know what the various tillage "products" will do, how much do they cost? Actually costs of implementing practices can vary considerably, from practically nothing to more than $100 per acre ($250 per hectare) depending on current state of the economy, abundance of farm fuel supplies, past emphasis on tillage programs within a watershed, cultural factors and the rate at which adoption is desired. Costs to encourage implementation can be grouped by increasing costs to the general public as follows:

1. Information-education programs,
2. Information-education plus technical assistance, and
3. Information-education, technical assistance plus monetary incentives.

In the Honey Creek watershed the highest cost incentive approach was used at approximately the following annual costs:

Information-education:	$25,000
Technical assistance:	$35,000
Landowner payments for tillage demonstration plots: and	$25,000
Special Agricultural Conservation Program cost share payments:	$12,000

In Table 3 calculations relating only landowner payments, either demonstration or cost share, to acre accomplishment show that application rates ranged from a high of $125 per acre ($312 per hectare) for no-till in 1979 to a low of $24 per acre ($60 per hectare) for reduced tillage in 1980. Note, however, that when acre accomplishments done without benefit of monetary assistance are included in the calculations, acre costs are lowered considerably, especially during the second year of the Project, 1980, where no-till cost $15 per acre ($37 per hectare) and reduced tillage, $5 per acre ($13 per hectare). In Honey Creek, benefits like these were due almost entirely to high quality on-the-farm technical assistance.

Table 3. Payments Made to Landowners for Implementing Conservation Tillage and Acres (Hectares) Treated by Practice During the First Two Years of the Honey Creek Watershed Project.

	Demonstration Project	$/Ac ($/Ha)	Special ACP Project	$/Ac ($/Ha)	Est. Other Acres (Ha)	Summary Effort	$/Ac ($/Ha)
			1979				
No-till $	17500	125	7117	28	-	24617	35
Ac(Ha)	140(56)	(312)	253(101)	(70)	300(120)	693(277)	(89)
Reduced Tillage $	10000	86	2170	29	-	12170	25
Ac(Ha)	116(46)	(217)	74(30)	(72)	300(120)	490(196)	(62)
			1980				
No-till $	17300	80	11589	25	-	28889	15
Ac(Ha)	216(86)	(200)	460(184)	(63)	1300(520)	1976(790)	(37)
Reduced Tillage $	2200	80	1478	24	-	3678	5
Ac(Ha)	28(11)	(200)	65(25)	(59)	600(240)	690(276)	(13)

Application costs per acre don't really tell the whole story, though, unless, of course, you are an expert at comparing apples with oranges. You might be able to compare such fruits in a supermarket, but not when shopping for point or non-point control practices. You really need to know how much it costs to keep a ton of soil or kilogram of phosphorus in a field rather than in a lake or stream. Practice effectiveness data from Table 2 plus incentive payment data from Table 3 provide one way of determining cost effectiveness of conservation tillage systems in reducing erosion (dollars/ton) and phosphorus yield (dollars/kilogram).

COSTS PER TON OF SOIL

In Table 4, calculations using this approach show that costs for keeping a ton of soil in place ranged from a high of $31 per ton ($34 per metric ton) for reduced tillage demonstration systems in 1979 to a low of $5 per ton ($6 per metric ton) for no-till done with ACP cost share funds in 1979 and 1980. When acre accomplishments done without benefit of monetary assistance are included in the calculations, costs are in the $2 to $9 per ton ($2 to $10 per metric ton) range, quite reasonable considering the nutrient value alone of a ton of soil is in the neighborhood of $8.

Table 4. Cost Effectiveness of Conservation Tillage Systems in Reducing Erosion, $/T/(MT), and in Reducing Phosphorus Yield, $/Hg, During the First Two Years of the Honey Creek Watershed Project. Note: 1979 Erosion, Phosphorus Reduction Data of Table 2 Applied to Both 1979 and 1980 Cost Acreage Data of Table 3.

	Demonstration Project		Special ACP Project		Other Acres		Summary Effort	
	$/T($/MT)	$/KgP	$/T($/MT)	$/KgP	$/T($/MT)	$/KgP	$/T($/MT)	KgP
				1979				
No-till	23 (25)	650	5 (6)	148	No cost		6 (7)	185
Reduced Tillage	31 (34)	833	10 (11)	289	No cost		9 (10)	248
				1980				
No-till	15 (16)	422	5 (6)	132	No cost		3 (3)	76
Reduced Tillage	28 (31)	800	9 (10)	237	No cost		2 (2)	53

COSTS PER KILOGRAM OF PHOSPHORUS

Calculations for phosphorus show that costs for keeping phosphorus in place ranged from a high of $833 per kilogram for reduced tillage demonstration systems in 1979 to a low of $132 per kilogram for no-till done with ACP cost share funds in 1980. Again, when other acre accomplishments are included, costs range from $53 to $248 per kilogram, substantially less than the initial start up or demonstration costs.

With regard to both soil and phosphorus, respective unit costs were in each case less during the second year, 1980. Projections over a 20-year period, assuming acres with conservation tillage to remain constant though that time, would show significant decreases in unit costs: $.10 to $.30 per ton of soil and about $3 to $12 per kilogram of phosphorus based on the summary effort data of Table 4. Annual costs of about $60,000 for information-education and technical assistance would be reduced similarly.

FARM ECONOMICS OF CONSERVATION TILLAGE

In final analysis, the purchase of any product, be it a box of soap or a tillage practice, must provide you something in return. In the case of conservation tillage systems, it must provide the farmer a means of existence. Economic data for one year only from tillage demonstration work in Honey Creek suggests that conservation tillage farming can keep an operator in business. Compared to an average net return of $85 per acre ($212 per hectare) for conventional systems, reduced tillage systems returned $107 per acre ($268 per hectare) while no-till returned $73 ($182 per hectare). Data gathered in years 2 and 3 of the Project will provide a better understanding of costs and returns to the farmer.

Table 5. Average Per Acre (Hectare) Production Costs, Crop Values and Net Returns to Farmers from Conventional and Conservation Tillage Systems, 1979 Honey Creek Demonstration Plot Data.

1979	Conventional	Reduced Tillage	No-till
Number plots	3	12	18
Average costs	192 (480)	180 (450)	198 (495)
Range	127 to 228	124 to 228	124 to 245
$/Ac($/Ha)	(318 to 570)	(310 to 570)	(310 to 612)
Average value	227 (692)	287 (718)	271 (678)
Range	252 to 307	155 to 381	166 to 325
$/Ac($/Ha)	(630 to 768)	(388 to 952)	(415 to 812)
Average return	85 (212)	107 (268)	73 (182)
Range	42 to 125	-13 to 179	-36 to 181
$/Ac($/Ha)	(105 to 312)	(-32 to 448)	(-90 to 452)

SUMMARY

This report attempts to describe what happened during the first two years of the Honey Creek Watershed Project, a 3-year demonstration Project within an agricultural portion of the Lake Erie Basin in north-central Ohio. While the data are by no means definitive, they provide insight as to the effectiveness and implementation costs of agricultural non-point source controls, particularly when planned as part of a start up or demonstration program. For such programs the data suggest that while practice application costs may initially be great, costs will decrease with time and as spinoff benefits occur.

In turn, implementation cost effectiveness of conservation tillage systems will increase. In Honey Creek costs decreased as a result of information-education and technical assistance efforts complementing incentive payments to landowners. Most effective of these was high quality on-the-farm technical assistance.

Now when you are shopping around for point or nonpoint source control practices, attempting to decide how much of which to implement where, you will have a rough idea of how to get the most from your money, at least with respect to conservation tillage practices. But when you shop, buy only what you need to do the job. Anything else would discredit the phrase, "best management practices."

REFERENCES

1. Cahill, J. H. and R. W. Pierson. 1979. Honey Creek Watershed Report. Buffalo District, U. S. Army Corps of Engineers, Buffalo, N. Y. 79 pg.
2. Wurm, D. U. and J. P. Crumrine. 1980. Honey Creek Watershed Project: Tillage Demonstration Results, 1979. Honey Creek Joint Board of Supervisors, Tiffin, Ohio. 61 pg.
3. Yaksich, S. M. 1979. Lake Erie Wastewater Management Study Methodology Report. Buffalo District, U. S. Army Corps of Engineers, Buffalo, N. Y. 146 pg.
4. Quilliam, R. 1979. Modern Farming with Conservation Tillage. USDA-SCS, Columbus, Ohio. 12 pg.
5. Logan, T. J. 1978. Summary Pilot Watershed Report Maumee Basin, Ohio. International Joint Commission Task Group C, Windsor, Ontario.
6. Spires, A. and M. H. Miller. 1978. Contribution of Phosphorus from Agricultural Land to Streams by Runoff. International Joint Commission Task Group C, Windsor, Ontario.
7. Schwab, G. A., E. O. McLean, A. C. Waldron, R. K. White, and D. W. Michener. 1971. Quality of Drainage Water from a Heavy Textured Soil. Transactions of the ASAE, Vol. 16, No. 6, St. Joseph, Michigan.
8. Romkens, M. J. M., D. W. Nelson, and J. V. Mannering. 1973. Nitrogen and Phosphorus Composition of Surface Runoff as Affected by Tillage Method. Jr. Environmental Quality, Vol. 2, No. 2.
9. Mannering, J., C. B. Johnson, and D. Nelson. 1977. Simulated Rainfall Study Results in Environmental Impact of Land Use on Water Quality. Final Report on the Black Creek Project-Technical Report, Allen County Soil and Water Conservation District. U. S. Environmental Protection Agency, Chicago, Illinois.

NONPOINT SOURCE POLLUTION IN URBAN AREAS

by

James Baumann, Andrea Domanik and John Konrad

The passage of the Amendments to the Federal Water Pollution Control Act in 1972, P.L. 92-500, set the stage for a major new initiative in our nation's water quality management program. This law provided for a comprehensive examination of the two sources of water pollution, point and nonpoint, and the development of a control strategy to deal with them.

Prior to that time, almost all water pollution control work was undertaken piecemeal with the great bulk of the effort being devoted to point sources of pollution. Nonpoint source (NPS) pollution is associated with pollutants contained in stormwater runoff and groundwater seepage. This diffuse pollution enters water bodies at an almost limitless number of places. Because of the difficulty of trying to deal with sources of this type and an inadequate understanding of the magnitude of NPS pollution, little effort had been directly devoted to its control. Indirectly, soil conservation efforts undertaken by rural agricultural interests have served to reduce the level of water pollution control associated with farmland erosion, but in urban areas the effort has been almost nonexistent.

Section 208 of P.L. 92-500 recognized the need to: examine nonpoint source pollution; measure the impacts in relation to those resulting from point sources; and develop a comprehensive control strategy which included best management practices to reduce pollution from both sources. In rural areas, the soil conservation experience has provided a basic implementation structure to build upon having identified control practices most likely to be effective. In urban areas no such focus has been available; instead, regional and state agencies were designated under Section 208 to generate the needed water quality studies and identify the practices and agencies needed to carry out the NPS water quality control program within urban areas.

The designated planning agencies in Wisconsin have undertaken in cooperation with state and university staff, a number of urban runoff investigations to determine the nature and extent of pollution resulting from urban runoff. The most significant work has been done in the Milwaukee and Madison Metropolitan areas. Four major studies have been undertaken in this southeastern corner of the Metropolitan areas. Four major studies have been undertaken in this southeastern corner of the state. They are: 1) The Menomonee River Pilot Watershed Study, sponsored by the International Joint Commission in the Milwaukee area, 2) The Washington County Project funded by the Environmental Protection Agency; 3) The Regional "208" studies undertaken by the Southeast Wisconsin Regional Planning Commission (SEWRPC) and 4) The Dane County Regional Planning Commission study for the Madison area. The first three studies mentioned are interrelated in that they all are focused on the greater Milwaukee Metropolitan area. Two agencies, SEWRPC and the Wisconsin Department of Natural Resources (DNR), played a role in each of the investigations. Information gathered in one study was often used in another.

This paper will synthesize the results of these and other studies with an aim to determine the type and effect of urban nonpoint sources of pollution in Wisconsin, their characteristics, and the overall strategy for dealing with these sources of pollution in the context of a comprehensive water pollution control program for urban and rural, point and nonpoint sources.

TYPES AND EFFECT OF URBAN NONPOINT SOURCE POLLUTION

Studies clearly indicate that urban nonpoint sources of pollution can cause serious localized water quality impacts on receiving waters and may have wider regional impacts. The two major types of NPS pollutants generated from urban land uses are (1) nutrients and sediments and (2) toxic materials In addition, some concern has been expressed about bio-chemical oxygen demand (BOD), fecal coliform bacteria, and chlorides.

It is important to recognize that both point and nonpoint sources contribute to water pollution problems. For example, SEWRPC had estimated in 1975 that only 19% of the perrenial streams (1,118 miles) and major lakes (100 lakes over 50 acres surface area) in Southeastern Wisconsin met the national goal of "fishable and swimmable waters". If only point sources were treated, by the year 2000, only 30% of the total stream miles and 18% of the major lakes could be expected to meet the national goal. The reasons why national goals would not be achieved are related to the contribution from nonpoint sources. Conversely, if only NPS controls were implemented, by the year 2000, 61% of the stream miles and 90% of the major lakes could be expected to meet national weather water quality goals. These figures illustrate the significance of nonpoint sources of pollution in this region of Wisconsin.

Perhaps the most immediately recognizable impact of NPS pollution in Wisconsin is the cultural eutrophication of lakes and streams resulting from the runoff of sediments and associated nutrients, especially phosphorus. This influx of excessive amounts of nutrients tends to accelerate the production of aquatic vegetation. The luxuriant growth of algae and rooted aquatic species impairs the recreational potential of these lakes and streams, alters the basic aquatic community and accelerates the filling of shallow lakes or impoundments. Phosphorus has probably received more attention that any other single pollutant in Wisconsin's NPS pollution control program. This is almost entirely due to its central role in the eutrophication process. Nitrogen is not identified as the controlling or limiting nutrient for most of the waters in Wisconsin and therefore has not been studied with same intensity.

In the Menomonee River Watershed, much of which flows through the City of Milwaukee, two-thirds of the total phosphorus load is from nonpoint sources. The other one-third is from point source discharges, most of it in soluble form discharged during nonstorm periods providing a very significant source of available phosphorus.1 This emphasizes the need to account for point sources of phosphorus, as well as nonpoint sources in order to have an effective control program.

Rural nonpoint sources of phosphorus also contribute very significantly to the water quality problems of Wisconsin, because of the large amount of farm land in the state. However, a recent study conducted in Dane County suggests that the average amount of P in the runoff from an acre of rural land is likely to be only one-half that carried in the runoff from an acre of urban land.

Sediment is a pollutant of considerable importance not just because of the nutrients, BOD, and toxics associated with it, but also because by itself it can cover and destroy and aquatic biological community, create conditions unsuitable for sensitive aquatic life such as trout, and may accelerate the filling up of lakes and impoundments. As will be discussed later, such problems with sediment may be especially severe near developing urban construction areas if adequate control measures are not adopted.

One characteristic of sediment as a pollutant which is important to understand in selecting control measures is sediment size. The relative surface area of a sediment particle is inversely related to the particle size. Therefore, the amount of surface area increases very rapidly as particle size decreases. Surface area also determines the quantity of pollutants which can be absorbed to these particles. This effect can be clearly seen in the concentrations of lead in the clay-sized particles found in suspended and bottom sediments in the Menomonee River, one of the rivers flowing through Milwaukee. Between 70% and 90% of the total phosphorus and lead is found in the fine, clay-sized fractions. These small sized particles, easily picked up and transported by a storm event, are also the most difficult to capture and control with most management strategies.

Toxics associated with heavy metals, other inorganic elements, or organic compounds constitute a public health hazard as well as a threat to the biolgoical communities of both lakes and streams. The toxics which have received the most attention in the studies have been lead, mercury, cadmium, chromium, copper, nickel, zinc, and PCB's. Aside from lead, the loadings of the toxics listed above appeared to be very low and their concentrations in surface waters are low as well. However, even though the concentration and loadings are low many of these pollutants persist in the environment, they attach themselves to sediment and accumulate in the bottom materials of the lakes and streams. Average concentrations of these substances in bottom sediments range from about 1,000 to 20,000 times the concentrations measured in flowing water in the Kinnickinnic River in Milwaukee. These toxics can have an adverse impact on bottom feeders and rooted aquatics, and during wet weather conditions some of these substances may be resuspended in association with the sediments. As with all of the pollutant parameters discussed these toxic substances are not derived solely from urban runoff, although such runoff is frequently the major source of these contaminants.

The fecal coliform standard in Wisconsin has been shown to be violated during periods of wet weather in the urban watersheds. This may or may not indicate the existence of a public health hazard. Fecal coliform is only an indicator of the possible presence of pathogenic or disease-carrying pollution. Since much of the fecal matter found in urban runoff is from nonhuman sources it is not thought to pose as serious a problem as that associated with domestic sewage.

Chlorides and BOD associated with runoff have not been demonstrated to present serious water quality problems in Wisconsin. This may be due to the dilution of these constituents in the large amounts of stormswater present during runoff periods. Chloride resulting from winter road salting activity has been shown in Madison's Lake Wingra to elevate concentrations, but the effect on water quality has not been determined.

BOD and associated dissolved oxygen problems have been tied indirectly to the phosphorus contained in urban and rural runoff. As pointed out previously, this phosphorus fuels the growth of algae and rooted aquatics; when the organic matter dies and decays it can exert a significant oxygen demand.

Overall there are significant water quality problems arising from pollutants contained in urban runoff in Southeastern Wisconsin. The most prominent of these are those associated with phosphorus. However, sediments and toxics can present serious problems as well. As developed areas expand and the required controls on the point sources are implemented, the overall amount and relative significance or urban nonpoint sources of pollution can be expected to increase.

CHARACTERISTICS OF URBAN NONPOINT SOURCES

When analyzing the extent and nature of urban nonpoint sources of pollution it is useful to differentiate between various types of urban land uses, because of the significant differences in pollutant loadings from these land uses. Two land-use related factors have been identified as having a significant affect on the amount of NPS pollution. The first is the hydraulic factor which measures the amount and duration of storm related runoff. Many types of urban development increase the amount of impervious surface and often alter natural drainage patterns. The general result of this type of development is to increase the amount of runoff and decrease the runoff period, thus increasing the intensity and velocity of the runoff event. This results in an increase in the scouring and transporting capability of the runoff water.

Another important hydraulic consideration affecting water quality is the impact of the increase in impervious surface (increased runoff) on the groundwater regime. The decrease in infiltration results in a lessening of the amount of groundwater derived baseflow available during low flow periods. These low flow periods are frequently the most critical periods from a water quality standpoint because the amount of water available for dilution is at a minimum.

The second factor is the differing types of pollutants generated by different land uses. Areas undergoing urban development are generally associated with disturbed vegetative cover and exposed soils. Such areas provide a very significant potential source of sediment. Industrial, commercial, and high density residential developments are generally associated with heavy transportation traffic and air pollution. The pollutants generated by cars and trucks, and fallout from air pollution caused by industrial production are usually deposited in the immediate vicinity of the source. An accumulation of these and other pollutants will occur because this type of development also has large amounts (a high percentage) of impervious surface.

The contaminants are then readily washed by storms into surrounding (available for transport to) surface waters. Especially important in this regard are lead and other toxic substances which are associated with transportation and industrial activity. Table 1 illustrates the variation in the approximate pollution generation potential for various urban land uses in the Menomonee River watershed.

Table 1. Pollution Generation Potential for Urban Land Use Categories In Menomonee River Watershed

Land use category		Suspended solids kg/ha/yr	Total phosphorus kg/ha/yr	Lead kg/ha/yr
1.	Industrial	5,100	4.46	6.9
2.	Commercial	3,450	1.51	13.2
3.	High density residential	3,650	2.77	5.6
4.	Medium density residential	3,100	2.46	4.2
5.	Low density residential	650	1.05	0.48
6.	Land under development	43,700	78.7	0.10
7.	Parks and recreation	460	.81	0.00

Source: Menomonee River Pilot Watershed Study, Summary Report, by J.G. Konrad, G. Chesters, and K.W. Bauer, May 4, 1978, p.o. 34.

Another indication of the relative seriousness of urban runoff from heavily built-up impervious urban areas can be seen in the General Mitchell Field Nonpoint Source Study undertaken in 1976 and 1977 by the Wisconsin DNR. General Mitchell Field is the primary commerical airport serving the Milwaukee Metropolitan area. It is located in a heavily built-up area on the south side of Milwaukee. This study found that storm water runoff from the airport area is a significant source of pollution to nearby streams. At times the concentrations of nutrients, suspended solids, and BOD approximate the levels found in raw domestic sewage.

Areas with storm sewers also tend to experience greater pollutional problems that those which lack such urban amenities. This may be easily explained by the above discussion concerning hydraulic factors and the types of urban land uses which would be associated with the presence of storm sewers. Storm sewers decrease the opportunity for infiltration and creates a very efficient runoff system. Storm sewers are generally associated with medium and high density residential, commercial, and industrial land uses. Table 1 demonstrates the potential reduction in pollutants which can be expected in nonsewered areas such as low density residential neighborhoods. It should be understood that the absence of storm sewers need not automatically be associated with a reduction in pollution problems, but rather if the hydraulic and land use characteristics associated with such a sewer are accounted for in the development of nonpoint controls then a reduction might be expected.

The intensity and duration of storm events is considered to have an important impact on urban pollutant loadings. Early thinking on this subject speculated that most pollution would be associated with the initial runoff resulting from a storm event; reduced loadings would occur as the storm continued since most of the pollution would be washed off in the "first flush".

The studies in Wisconsin indicate instead that with one exception, the total mass of pollutants washed from urban land surface, is directly proportional to the volume of precipitation associated with the event; pollutant concentration is relatively insensitive to the volume and duration of the storm event. This may be caused by the more intensive scour and transport capacities of larger volumes of water and the large reservoir of pollutants available for transport in the areas studied.

Snowmelt runoff during thaws in the winter and early spring provides an exception to these findings. The Mitchell Field study determined that the greatest seasonal pollutant yield did not occur during the season generating the largest runoff volume, summer, but rather during the season with the least runoff volume, winter, for all constituents, except suspended solids. This can be explained by the accumulation rates, differences in storm event characteristics and the presence of frozen pervious surfaces. Investigations of winter and spring snow melt events are very sparse, and a great deal of work remains to be done in this area.

In summary, not all urban areas contribute equally to the pollution problem. Developing urban areas are by far the most significant sources of sediments and associated phosphorus. The amount of impervious surface contributes both to the increases in the volume, scouring, and transport capability of storm water and contributes to the build-up and availability of pollutants. The amount of impervious surface and industrial land uses which are associated with this type of impervious surface are found to be the most significant sources of toxic pollutants and may also contribute important amounts of sediment and phosphorus.

MANAGEMENT STRATEGY

In the development of a management strategy to control urban nonpoint sources of pollution it is essential that clear-cut water quality objectives or standards be formulated and that point sources and rural nonpoint sources of pollution are considered in a comprehensive and integrated fashion. The lack of clearly established and agreed upon water quality objectives for NPS pollution has been an obstacle in developing an overall water quality management strategy.

Three aspects of this urban problem are the most difficult to assess. They are: (1) The absence of an established standard for phosphorus in either lakes or streams, (2) The lack of guidance in dealing with acceptable levels of toxics in bottom sediments, and (3) The inadequacy of the present water quality standards to deal with high flow periods.

The SEWRPC areawide water quality management planners have taken major initiatives toward dealing with these problems. They have employed a complex water quality model (HYDROCOMP) to simulate the inter-relationships between the various sources of pollution, anticipated storm events, hydraulic characteristics of the area and water quality conditions. This model, within various levels of confidence, is then able to predict the water quality expected when employing alternative point and nonpoint source control strategies. They have applied a total phosphorus standard of 0.10 mg/l for flowing streams and a 0.02 mg/l concentration in lakes during the spring turnover period. These are not standards which have been officially adopted by the Wisconsin DNR, and they have been subject to widespread scrutiny and criticism. However, it must be pointed out that these are the concentrations provided in EPA's Water Quality Criteria - 1976, the so-called "red book", and no one has suggested more appropriate concentration limits.

The water quality model also allows SEWRPC to take a new approach to the application of water quality standards. This approach considers the assessment of the proportion of the total time under various anticipated flow conditions can be expected to exceed specified concentrations, such as that listed above for phosphorus which do not directly affect aquatic organisms, but are primarily related to recreational use. This statistical approach was not employed for concentrations of toxic materials under the presumption that these materials should never be present in toxic concentrations in the water body. SEWRPC did not directly address the control of toxic levels in the bottom sediments.

In developing a specific control strategy for urban nonpoint sources it is necessary to consider the character of this type of pollution. There are four key considerations in this control strategy. (1) Control of the sediments, especially the clay-sized particles to which phosphorus and toxic compounds are adsorbed. (2) Concentrate first on those land uses which provide the most significant sources of pollution, specifically developing areas and those parts of the city where residential and industrial urban land uses are densely concentrated. (3) Develop measures which increase the amount of infiltration and reduce and attenuate the amount of overland flow. (4) Prevent the pollutants from being generated in the first place.

Since virtually all significant types and amounts of urban nonpoint sources of pollution are associated with sediments, the control of sediments is an important consideration. In effect, almost all cost-effective control strategies are aimed at either keeping these sediments in place, removing them from impervious surfaces, or causing them to be placed in areas where they will not be eroded and carried into surface waters.

An exception to this general rule of concentrating on sediment control are actions which prevent associated pollutants from being generated at all. This can be seen in the ban on leaded gasoline, control on industrial air emissions, and limitations on various types of fertilizer and pesticide use. It is anticipated that the control on the use of leaded gasoline will take care of most of the problems currently experienced with lead pollution.

RESIDENTIAL HOUSING CONSTRUCTION

The most promising area for overall control is in developing or redeveloping urban areas. In the Menomonee River watershed developing urban areas represented only 2.6% of the total area of the watershed, but contributed 37% and 48% respectively of the suspended solids and total phosphorus at the river mouth. Data from the Washington County Project showed that subdivisions constructed without preventative measures to reduce soil disturbance contributed significantly to water quality nonpoint source problems (Washington County Final Report, November, 1979). In the Washington County Project, sources of sediment and methods of controlling sedimentation were studied for three phases of the residential construction process: 1) site selection and plat planning, 2) plat development of streets and services, and 3) lot by lot house construction. Housing construction was emphasized because this phase of development has not been critically evaluated as contributing to the sediment control problem. Legal mechanisms for regulating subdivision construction activities at the local level were also examined.

Site Selection

One of the best methods for minimizing erosion and sedimentation may be proper environmental planning prior to development. A high degree of quality may be achieved without increasing development cost; this is accomplished through proper selection of sites suitable for development and sensitive plat planning and development. When investigating potential development sites, physical and natural conditions should be critically evaluated. Areas with unsuitable soil types, lowlands, steep slopes and high water tables (to name a few limitations) would be expensive to develop, requiring extensive filling or grading, difficult to minimize erosion, and troublesome to maintain. Preparation of the plat plan should take into account such factors as natural drainage patterns, existing vegetation and the amount of land disturbance necessary to develop the plat. An effort should be made by developers to minimize the degree to which the landscape will be altered particularly with respect to drainage. When necessary, erosion and sedimentation controls should be incorporated into the plat plan.

Plat Development

Plat development can be viewed as the construction of streets and services. Numerous publications have been written offering suggestions for reducing sediment loss during this stage. One common development practice has been to strip topsoil and vegetation from the entire plat then proceed with construction. Often the topsoil is stockpiled for several years while streets and services are being built. A more environmentally source practice would be to only disturb the area where construction is currently concentrated or to protect large areas of exposed soil. If topsoil must be removed, temporary measures to protect the exposed soil should be taken. Seeding, mulching or other protective covers would achieve adequate control.

Other innovative measures can be implemented to minimize stormwater runoff; porous pavement and protective buffers or berms increase stormwater infiltration. It is critical that all control measures be incorporated into the plat plan, thus insuring enforcement and implementation.

Housing Construction

Construction of residential dwellings within a subdivision can cause large amounts of sediment to be transported through storm sewers to surface water. The problem is magnified by the simultaneous construction of several dwellings. Table 1 illustrates monitored sediment yield during uncontrolled housing and construction (Washington County Project). Three subdivisions being rapidly developed were monitored during 1977. No treatments for erosion and sediment controls had been used. The amount of sediment, measured as suspended solids, leaving the subdivision through its storm sewer, has been estimated in kilograms per hectare per year. Differences in site conditions may account for variations in annual yield. No comparable values are currently available for treated residential construction activity.

Table 1. Annual Suspended Solid Yield (kg/ha) From Untreated Residential Construction in 1977

Station	Yield
G2	27,215 kg/ha
G3	17,365 kg/ha
G5	13,148 kg/ha

Building practices common during construction, that were examined in the Old Farm Annex, might be mitigated without interfering with construction. The following list, by no means complete, attempts to highlight damaging activities and conditions:

- Exposed and unprotected soil throughout the subdivision (highly erodible).

- Excavated soil, in large mounds, placed near and often in the streets (rapid erosion and delivery of sediment to storm sewers).

- Unlimited access to lots by vehicles and heavy equipment (tracking soil adhered to tires into streets; gullies formed by tire tracks that channelizes flow).

- Pumped water from flooded basements (dewatering) onto exposed areas (generates and transports sediment to storm sewers).

- Drained rooftop runoff onto unprotected areas (forms gullies, erodes and transports sediment to storm sewer system).

Many of these activities occur during work performed by subcontractors who are onsite for a very short time. Cooperation and communication between builders and subcontractors are essential if mitigating measures are to be effective.

On-Site Controls

The following list of practices are divided into two categories, those that do not require additional funds to implement but are suggestions for timing activities to reduce impact. Other practices do have a minimal cost but are usually incurred at some point during construction. It is recommended that many of these measures be implemented early in the building process so that their benefit will be incurred throughout the housing construction period (which takes from four to six months).

No Cost Practices: 1. Retain existing trees and shrubs wherever possible, since vegetation filters, retards and absorbs overland runoff.

2. Locate excavated basement soil a reasonable distance behind the curb, such as in the backyard or sideyard area. This will increase the distance eroded soil must travel to reach the storm sewer system.

3. Remove excess soil from the sites as soon as possible and rough grade the lot. This will eliminate large soil mounds which are highly erodible and prepares the lot for temporary cover.

4. If a lot has a soil bank higher than the curb, a trench or berm should be installed moving the bank several feet behind the curb. This will reduce the occurrence of gully and rill erosion while providing some storage and settling area for sediment-laden storm water.

5. Roughen the soil surface by rototilling areas that are to be stripped for too short a length of time to allow establishment of temporary vegetative cover. Roughening will increase the infiltration of storm water and reduce erosion.

6. Direct flowing water away from steep slopes and other highly erodible areas by constructing diversion structures such as terraces, benches, dikes and ditches.

Other Practices: 7. Provide for periodical street sweeping or vacuuming to remove sediment during construction.

8. Stabilize the lot by seeding and mulching or sodding as soon as possible after exterior construction is completed. This will minimize erosion as well as make the area more visually pleasant.

9. When not feasible to stabilize the entire lot with vegetation, cover an area approximately 20-30 feet behind the curb with a protective material such as filter fabric or mulch and netting. This covering may be installed before backfilling, provided excavated soil is placed in the backyard area and the lot has been rough graded. Lateral lines may be installed by removing the protective covering and then replacing the cover after filling. This measure will reduce raindrop intensity while protecting the soil.

10. Apply 1-inch gravel to the driveway area and restrict truck traffic to this one route. Driveway paving can be installed directly over the gravel. This measure will eliminate soil from adhering to tires and being tracked into the street.

11. Install roof downspout extenders and sump pump drainage tubing to disperse water or to divert it directly to the curb and stormsewer. Keeping clearwater from running across exposed soil will prevent gully and rill erosion from these sources.

12. Install straw bales, sand bags, tarps or filter fences along curbs to reduce the amount of eroded soil reaching the curb gutter or stormsewer.

Legal Controls Case Study

Many states, counties and incorporated areas have enacted some type of ordinance that attempts to control subdivision developments. In Washington County, developers are required to submit preliminary plat plans to the County Soil and Water Conservation District for proposed developments within unincorporated areas. This subdivision ordinance is fairly modest requiring a land suitability test where lands with greater than 12 percent slope are presumed unsuitable for development unless developers can provide adequate erosion and sediment controls. The ordinance also requires stormwater management facilities be designed to handle the maximum flow potential from a 10-year 24-hour storm. If development requires substantial land disturbing activity, practices to minimize erosion and sedimentation are required. Several towns within the county have adopted the county ordinance. Washington County's subdivision ordinance does not, however, address the lot construction phase of development. It also does not apply to unplated housing construction (less than five lots). There are limited provisions for enforcement and penalties. Authorities are not defined stating who is responsible for monitoring compliance with this ordinance and insuring implementation of required erosion and sediment control measures.

The Village of Germantown has drafted a land division ordinance requiring plat review by the Village Engineer and County Soil and Water Conservation District. Maps of the natural and physical conditions within the proposed development are required in order to determine suitability. Soil and water conservation practices are also required where land disturbing activities are proposed. Developers are required to minimize the amount of area exposed and must stabilize by revegetating as soon as practical. In an attempt to control lot construction, the Village has also developed an ordinance that requires builders to post a $100 cash bond when applying for a building permit. The bond will be used to pay for services, if any, incurred by the Village because of construction activity; any remaining money will be returned to the builder upon issuance of an occupancy permit. The ordinance also levies a $200 per day fine on any person, firm or corporation found guilty of violating the ordinance.

In order to provide for the control of erosive construction practices, subdivision and building ordinances should be strengthened to include:

- tracking provisions requiring vehicle traffic to clean sediment in the street as a result of their tire tracking;

- handling requirements for excavated soil so that soil is placed behind a set back line or tied to an egress line, from the house front to the curb line;

- placing limits on the amount of time soil can be exposed and require temporary protection;

- providing for the periodic cleaning of sediment from streets and gutters during construction;

- limiting alterations in natural drainage patters or provide for retention of stormwater resulting from channelized drainage ways; and

- requiring that rooftop runoff be diffused onto vegetative areas and provide for the proper handling of pumped water (from dewatering or sump pump activity).

By including these provisions into ordinances that control land disturbing activities, environmental and aesthetic qualities will be greatly improved.

Experience on the Washington County project has demonstrated that a three pronged approach is needed to effectively implement a program for control in these developing and redeveloping areas:

They are:

1. An informational and educational program to explain the need for erosion and sediment control during construction.

2. Standards and design specifications for erosion control practices written in understandable language.

3. Cooperation between local officials and developers, builders and subcontractors in setting reasonable and effective regulations.

DEVELOPED URBAN AREAS

The outlook in developed areas is less optimistic. Most of the available controls are relatively expensive and questionably effective. Surprisingly, the most effective control measures may be instituted in parts of the city now served by combined sewers.

Dry weather street flushing can be employed prior to comprehensive actions to control the combined sewer overflow problems. Such flushing can transport street contaminants to municipal treatment plants and dislodge deposits in the sewer. Eventually, in the elimination of combined sewer overflows some form of storage and treatment can deal with both point and NPS pollution problems, if properly designed. SEWRPC is recommending such a method to deal with pollution problems in the combined sewer areas of Milwaukee.

In the other developed urban areas only very carefully selected management practices should be recommended for implementation. The most commonly discussed, street sweeping, does not appear cost-effective under most conditions, but may be useful if employed for spring clean-up and during autumn leaf drop periods. Certain housekeeping activities such as catch basin cleaning and redirecting roof drains to areas where infiltration will occur may also be useful. The most effective actions may be those mentioned previously which prevent the generation of the pollutants. Regulations on the generation of leaded gasoline and on materials handling as well as air pollution controls are examples of such action.

CONCLUSIONS

Urban runoff is a major contributor to the water quality problems being experienced in and near our major cities. The eutrophication of our valuable lakes, as well as the degradation of the streams can be traced to urban nonpoint sources of pollution in these areas. As our metropolitan areas expand and point sources of pollution are brought under control, the relative importance of urban nonpoint sources will increase even more. Any water quality management strategy for our metropolitan areas which ignores or downplays this source of pollution is destined to be ineffective in the attainment of the national goal of fishing and swimming water quality.

Stormwater runoff from urban and developing areas have unique hydrological characteristics which requires special consideration in order to control nonpoint sources of water pollution. As impervious ground cover increases the area's hydrology changes so that stormwater does not infiltrate, but rather the volume of water running off increases. Therefore, more water is available to transport pollutants through storm sewers and roadside ditches to surface waters. Degradation of surface waters accelerates as more polluted water enters, ultimately affecting their recreational and natural amenities. Control strategies that increase infiltration or retention time within urban areas should be investigated.

The urban runoff program will, in all probability not be as effective or cost-efficient as it should be until comprehensive programs are developed which examine all sources of pollution and their relationships. Standards must be developed which deal with high flow periods. The control of sediments from developing urban areas, special consideration for nonpoint source pollution in dealing with combined sewer overflows, and the elimination of pollutants at the sources in other developed areas seem to provide the most promising means of dealing with pollution contained in urban runoff.

Stormwater runoff from residential subdivisions that are undergoing development can generate and transport large amounts of sediment and associated pollutants (nutrients, metals) to surface waters. Low cost practices are available to reduce sedimentation during the lot construction phase of development. Subdivision and building ordinances should be strengthened to include erosion control practices.

Authors are all members of the Bureau of Water Quality in the Wisconsin Department of Natural Resources, Madison, Wisconsin.

NURP

by

Doug Ehorn
Chief, Michigan Water Quality Management

The purpose of this speech is to present you with an up-to-date summary of progress made under the National Urban Runoff Program. While there are many attendees in this room who are familiar with the NURP program there are several new faces and therefore I'll first present a brief historical statement.

HISTORY

Over the past several decades, several studies conducted across our nation indicated that storm runoff was a major pathway through which pollutants were carried to receiving waters. Under the Federal Water Pollution Control Act (PL 92-500) there was an initial way to fund storm water projects in conjunction with the construction grants program. However, storm control was not regarded as a critical element which initiated grant action, but oncillary and should be studied to provide cost-effective solutions to pollution control. And even then the major of funds were to be spent combined sewer overflow controls or Abatement. With the later amendments to the Act, there was less emphasis put on storm water control for a variety of factors; the main factor being that there was an insufficient data base to support the program.

During the last three years, studies conducted with Section 208 planning funds have supported the concept that urban runoff appears to be a major pathway of pollution. Studies were conducted at numerous locations on a nationwide basis. Even with this expanded data base, Congress did not provide sufficient funds to expand the program to any great extent. They did provide funds for problem assessment and planning, but held back on implementation funds because the current state of technical knowledge was insufficient to justify large-scale actions.

The National Urban Runoff Program was initiated to respond to several of the prominent deficiencies such as: areal accumulation patterns, washoff, transport, instream behavior of pollutants and effectiveness of control measures. The EPA hopes that the current studies will provide knowledge concerning the practical implications of urban runoff pollutants on water quality and aquatic ecosystems. Several of the goals envisioned when the NURP program was initiated in 1978 was to gather knowledge that would provide a holoistic approach to the problem and the state of the art for control technologies that would provide EPA, the States and local decisionmakers with a rational basis for problem assessment, postulation of controls, and development of local stategies to implement controls that would show benefits to the receiving waters. To date NURP 30 projects at a cost of $20,658,000 have been funded with the intent of providing a report to Congress in 1983 to support further planning and implementation activities. The report will have to deal with the nature, and extent of runoff problems, cause of the problem, severity of the problem (based on beneficial uses and WQ standards of receiving stream) and the opportunities for controlling the problems.

Where are we today?

The EPA has substantially completed the initial phases of the NURP Program at the present time. A nationwide program was developed and current status of problems was assessed, projects were selected to provide a "Prototype" base. Program management and coordination is continuing with headquarters providing technical assistance to the projects. I might add that even though liaison functions were rough during the initial year of NURP, both Headquarters and the the Regions have been able to develop a "report" that provide excellent service to the grantees.

As data from the prototype projects is gathered, reduced to usable form and provided to the EPA, the process of Program assessment and evaluation will begin in earnest. The culmination of all these activities is the already mentioned report to Congress in 1983. While EPA will not fund any more NURP type projects during the planning process, we are anxious to supply all relevant data and control strategies to local planning and implementing agencies at the earliest possible date.

By the way the report I have with me entitled "Quarterly Progress Report, National Urban Runoff Program" provides initial data on management aspects of the NURP program. It does not provide data on control mechanisms, BMPs, pollutant sources or other technology aspects of the program due to early stage of NURP development.

Of the 30 projects that were targetted for NURP, 10 projects are underway and yielding data, most of these projects have their planned BMPs in operation. Ten projects are just beginning. Their work plans are approved and consultant contracts have been signed. Nine projects do not have fully approved work plans and one project is in an early stage of planning. I should note that projects which started late had the most difficulty achieving approval because of the keen interest and insight provided by EPA's technology consultants who required ever increasing high standards of performance.

The General characteristics of these prototype projects are summarized as follows:

A. Receiving water type (by major emphasis)

8 projects study small streams
5 projects study lakes
6 projects study rivers
1 project studies oceans
2 projects study groundwater

B. Impacts

9 projects study actual impairment of beneficial use
8 projects study standards violations
4 projects study public concern

Impacted beneficial uses fall into 5 major categories: water supply, contact recreation, non-contact recreation, fish and wildlife, aesthetics

C. Suspected Problem Pollutants

1 project studies BOD, COD, DO
8 projects study nutrients
1 project studies sediments
7 projects study heavy metals
1 project studies other toxics
7 projects study coliform bacteria

D. Major Best Management Practices

4 projects study street sweeping
4 projects study Detention basins
1 project studies Catch basin cleaning
2 project study wet land treatment

There are other practices being studied at localized site including: swirl concentrators (which offer great promise), runoff ordinances, sewer alternatives and filters.

Technological status

The EPA is concerned about the potential threat of urban runoff to the Great Lakes ecosystem. Currently projects have not progressed far enough to provide sufficient details that would warrent a generalized status statement. From the early data, this Agency is aware that toxic pollutants in urban runoff may not have received sufficient attention at this time. One report from the Seattle study indicated that toxics could be a localized problem, however the data base was not as good as it might have been. New analytical methods are being devised to overcome problems. At another location high concentration of Salmmella were found and in the Final Report for the Castor Valley project measurable asbestos levels were indicated.

As you can tell the data base is slim at this time. Several projects are being realigned to provide answers to questions arising from earlier projects or to take advantage of developing technologies.

My best advise to you is..., Use your head make logical decisions, well thought out, not under pressure. For instance street sweeping projects may not work because you don't pick up fine materials that carry pollutants. Then proper disposal methods timing of sweeping. For Detention basins - longer detention time to get fines settled out. These are just a few of the logical things that must be done. I believe that small, well organized projects will probably give us more pertinent data than the large megabuck projects.

The Future of NURP

We are just beginning to crawl in certain aspects of urban runoff and its technology. We are certain that pollutants are reaching receiving waters in our urban areas. Further quantitative work must be accomplished in the areas of sources and control of sources. The EPA does have sufficient knowledge concerning wastewater treatment plans and our data base is growing on combined sewer overflow control and sludge. However in the area of separate storm water discharges there is a paucify of data.

NURP's future is uncertain at this point. Very preliminary data indicates that there is no real problem in some areas. Urban runoff may not be a National problem. In that case, controls and strategies would have to become concentrated in localized areas.

The pollutant of most concern that has emerged from the early studies is bacteria. So what? What does that mean in terms of beneficial uses or standards. From a public health aspect we have found certain discharges to be laced with Salmonella and animal coliform. These results will have to be followed up on.

There was some early data to indicate that all nonpoint sources were significantly contributing to degradation of water. These studies are reconfirming that fact on a localized basis. It appears to me that the upshot of all this is--Nationally we are going to have to re-look at out water quality standards after sufficient nonpoint source data is available from programs similar to the NURP program.

Let me encourage everyone who is interested in pollution control to do their utmost to make available good data that can contribute to our knowledge of causes, effects, and solutions to pollution of our National waters.

LFW/ib
WIBLE-F

HIGH FLOW WATER QUALITY STANDARDS

By

Lyman F. Wible[1]

INTRODUCTION

This paper discusses high flow water quality standards as they have been addressed in the areawide water quality management planning program of the Southeastern Wisconsin Regional Planning Commission (SEWRPC). This discussion will include the need for standards, the analyses and resulting approach taken by SEWRPC, and the more recent actions taken by SEWRPC, and the Wisconsin Department of Natural Resources (DNR) and the U.S. Environmental Protection Agency (EPA) to further address the question.

The Southeastern Wisconsin Region includes the seven counties in and around the Kenosha, Milwaukee, and Racine metropolitan areas. As the designated areawide water quality management planning agency for the Region, SEWRPC addressed three generalized questions in preparation of its Section 208 plan. Here are the questions: first, what are the historic trends in water quality and in the attainment of the state and federal water quality standards? Second, what are the existing sources of water pollution which affect water quality? Third, what are the future actions which will be necessary in order to achieve and maintain the water quality standards in the 1,180 miles of continuous stream and in the 100 major lakes in southeastern Wisconsin through the year 2000?

In this process, the development of meaningful quantitative plans required the use of analytic tools. Such tools can be applied only in the framework of explicit quantitative planning standards. Planning standards provide the basis for comparison of current conditions, the current trends, and the alternative plans for water quality management. The Southeastern Wisconsin Regional Planning Commission has always developed planning standards of this sort in order to serve specific use objectives. The Section 208 planning process addressed program objectives for supporting sound land use, supporting the intended water uses, protecting the natural resource base, developing a cost-effective plan, and establishing effective and locally acceptable implementing mechanisms. For each of these program objectives, a series of quantitative planning standards was developed.

At this juncture, a definition must be clarified. Since 1967, the Wisconsin Department of Natural Resources has referred to the intended use of a stream as a "use designation" or "use classification". The Regional Planning Commission--in the framework of definitions developed in comprehensive planning since 1961--refers to these as "water use objectives," objectives to be achieved by action in various programs. The objectives include, in various combinations, the maintenance of a trout fishery and related aquatic life, the maintenance of a salmon fishery and related aquatic life, the maintenance of a warmwater fishery and related aquatic life, the maintenance of a limited fishery and related aquatic life, recreational use, limited recreational use, and the maintenance of minimum water quality conditions for the avoidance of nuisance or aesthetic offense.

---

[1] Chief Environmental Planner, Southeastern Wisconsin Regional Planning Commission, Waukesha, Wisconsin.

The attainment of these objectives may be measured against specific standards, as discussed above. Among these standards are what SEWRPC calls the "water quality standards," which are referred to by the Wisconsin DNR as "water quality criteria". In this paper I will utilize the Regional Planning Commission's definitions, which recognize water use objectives and supporting water quality standards as being among the set of multiple objectives and supporting standards to be addressed and evaluated in the development of a meaningful, comprehensive plan for water pollution control. I will address standards for flowing streams, since the issue of water quality standards definitions for lakes includes a substantial body of literature and technical work which could not be addressed properly in these brief comments.

Clearly, the basic water use objective which was sought to be achieved in the development of the Section 208 plan was the attainment of water suitable for the maintenance of fish and other aquatic life and for the support of human recreation in and on the water: in other words, "fishable and swimmable" water quality conditions. Only upon the basis of (1) specific findings regarding limitations due to natural conditions, or due to (2) irrevocable human modification of the watershed and drainage system were the nationally identified water use objectives compromised in the development of the Section 208 plan.

It should also be noted that this approach differs from the use of water quality standards by state and federal agencies. The U.S. EPA and the Wisconsin DNR, being regulatory agencies, utilize water quality standards as the basis for enforcement actions and for compliance monitoring for current conditions. This requires that the standards have a rigid basis in research findings and in field experience. By contrast, the Regional Planning Commission must anticipate regulations and technologies into the future, documenting the assumptions used to analyze conditions and problems which may not yet exist. As a result, more recent--and sometimes more controversial--study findings must sometimes be applied. This results from the Commission's need to use water quality standards as a criterion to measure the relative merits of alternative future conditions.

A classic example of the need for appropriate quantitative planning standards, as a basis for plan alternative comparisons, may be found in the determination of point source and nonpoint source tradeoffs in the Section 208 planning process. Intuitively, the most cost-effective solution to water quality problems in any given area would appear to include combinations of point and nonpoint source pollution controls. However, if as a basis for comparison of alternative plans, a low-flow-based water quality standard (for example, the seven-day-average, one-in-ten-year-recurrence interval, low-flow condition) were used exclusively, then the stream response to point source controls would appear exaggerated. If the average annual pollutant loads to a surface water system were used exclusively, this measure of effectiveness may indicate an exaggerated response to nonpoint source controls. However, a fair comparison of the two types of sources requires a planning standard or a combination of planning standards expected to be responsive to both types, in those cases where both are important.

Historically, water quality management efforts at all levels have been oriented toward the dry weather, low flow problem. Water pollution problems have generally been considered most apparent when the stream flows decline significantly during dry weather. By contrast, the point sources of pollution normally discharge sewage effluent at a relatively constant rate or at a uniform frequency, and of a relatively uniform quality; and are relatively less affected by changes in weather conditions than is the associated stream flow response. These concerns have also led to consideration of dissolved oxygen as the most critical water quality indicator. Thus, water quality management programs have been designed to attempt to control point sources of pollution by specifying appropriate sewage treatment plant effluent limitations. The effluent limitations are chosen with the intent to ensure that in-stream water quality standards are met during all but the very lowest of stream flow conditions. At higher flows, the dissolved oxygen standard was considered to have been attained, because of the dilutional effects of the receiving stream.

Recent water quality monitoring programs have indicated that water pollution is not exclusively a dry weather, point source-related problem. As evidenced by the water quality monitoring results documented in the SEWRPC continuing water quality monitoring program since 1964, numerous violations of water quality standards have been known to occur under conditions other than dry weather low-flow conditions, and as a result of sources other than point sources of pollution. Accordingly, it was determined in the Section 208 program for southeastern Wisconsin that the recommended plan must address the surface water quality problems attendant to high flow--as well as low flow--conditions.

To formulate the applicable water quality standard which would support the intended water use objectives, an analysis was made of water quality monitoring data from those streams in the Region that have relatively clean water and healthy fisheries, and for which the water use objectives are considered to be met at the present time. Review of these data indicated that even in such relatively clean streams, the specified water quality standards are not met all of the time. Standards violations were found on occasion, but were generally of such short duration and low intensity that these violations would not be expected to adversely affect fish and aquatic life and the human use of the surface waters. Therefore, it was concluded that it would be impractical to interpret water quality standards on an absolute basis--that is, as being required to be met 100 percent of the time. Accordingly, it was determined to assess water quality conditions against the pertinent water chemistry criteria on a probabilistic basis, specifying in effect the percent of total time that the water quality conditions were to be in compliance with the water quality criteria. This approach was subject to the requirement that point source pollution abatement measures would continue to be designed to meet these standards during the seven-day average one-in-ten-year recurrence interval low-flow condition in receiving streams. Thus, the interpretation would provide for standards to be violated for extremely low flow conditions and for a specified proportion of time under relatively high flow conditions. This constitutes a risk assessment procedure, and is reinforced by the recognition that a finite probability exists--typically in southeastern Wisconsin, on the order of one-tenth of one percent--that the seven-day, one-in-ten-year recurrence interval design would be inadequate as well.

Further analyses were made to determine the percent of time that a given standard should be allowed to be violated. A 95 percent compliance level was selected as a practical criterion for meeting the water quality standards for those indicators which directly affect desirable forms of aquatic life. These included dissolved oxygen, temperature, un-ionized ammonia nitrogen, and pH. A 90 percent compliance level was selected as the criterion for those indicators which do not directly affect desirable forms of aquatic life. These include phosphorus and fecal coliform organisms. The Commission analyses indicated that if these compliance levels were met during periods other than extreme low flow conditions, the duration of violation would be expected to be relatively short and the intensity would be relatively low. Thus, desirable forms of aquatic life should not be adversely affected. This probabilistic approach to the interpretation and application of water quality standards formed a very important basis for the evaluation of alternative plans and the selection of a recommended plan, by considering the effects of nonpoint sources of pollution. It was therefore recommended that this probabilistic approach to water quality standards and interpretation be considered by the state for use as a supplement to the current exemption in State standards for low flow conditions, flows below the seven day Q_{10}.

This approach has been recommended to the Wisconsin Department of Natural Resources for all of the standards supporting the water use objectives used in the preparation of the Section 208 plan. The recommendation renders it more complex to interpret a field-sampled water quality violation: is the observed condition a member of an acceptable and infrequent set of occurrences, or is it representative of a "polluted" condition having an unacceptable frequency of violation. This procedure will require the Department of Natural Resources to develop new field techniques, or interpretive methods for the analysis of field survey data as presently gathered; or to develop a set of assumptions regarding the probabilities of standards violation associated with what had been historically recognized as "background" or "natural" conditions, which interfered with achievement of water quality standards by point source control. It is now apparent that the effects of uncontrolled nonpoint sources must be differentiated from the effects of "natural" limitations of the surface water systems.

The results of the Regional Planning Commission's approach were checked for reasonableness against other study findings. Such comparisons considered the SEWRPC adopted Regional Sanitary Sewerage System Plan completed in 1972, and within the framework of point source pollution control; the Department of Natural Resources' wasteload allocation studies and resulting effluent limits; the "common sense" recommendations of long-standing soil and water conservation agencies; the recommendations of the Menomonee River Pilot Watershed Study conducted by the International Joint Commission; and the findings of Washington County Sediment and Erosion Control Study conducted under Section 108 of PL. 92-500. The SEWRPC results were found to be consistent with the results of these other studies.

The Regional Planning Commission believes that the work which was conducted as part of its Section 208 program can serve as a point of departure for analysis and further development of solutions to this relatively new problem regarding water quality standards for high flow conditions. The technique utilized by the Commission was practical for its work programs, since the hydrologic-hydraulic water quality simulation model (Hydrocomp) which was applied, gives results in a probability distribution of the water quality indicators studied. However, the Commission staff believes that the probabilistic interpretation of standards and of in-stream water quality samples may be capable of more simplified application, by use of nomographs, charts, or figures, if these tools are properly and rigorously developed. The extension of an approach to high flow water quality standards is one of the major goals of the "Phosphorus and High-flow Assessment Study for Water Quality Standards." This project is currently being conducted by the Department of Natural Resources in cooperation with the EPA and SEWRPC. The project is being undertaken in part as a result of the DNR inclusion of this matter as a "highlighted issue" in the Wisconsin-EPA Agreement for fiscal year 1980. The project has initiated studies of the related aspects of biological field monitoring of aquatic flora and fauna, biomass estimates, pollutant-mass load analyses, and bioassays. The project is also evaluating the potential for inclusion of biological parameters into analytic and simulation models.

The SEWRPC staff believes that with thoughtful consideration, the effects of nonpoint sources of water pollution can be properly addressed in the water quality standards and in the related water quality monitoring and enforcement programs.

THE USE OF COMMUNITY PARAMETERS DERIVED FROM ELECTROFISHING CATCHES OF RIVER FISH AS INDICATORS OF ENVIRONMENTAL QUALITY

by

J. R. Gammon

Professor of Zoology, Department of Zoology, DePauw University,
Greencastle, Indiana 46135

Acknowledgements

The analysis presented in this paper is based upon research supported by Public Service Indiana, Dayton Power and Light, Eli Lilly Company, and the Office of Water Resources Research. Field collections involved many students including Terry Teppen, Chris Yoder, Doug Meikle, Brandon Kulik, Jim Thayer, Michael Stroup, Doug Bauer, Robert Gammon, Rick Wright, and Ernest Roggelin. The system of data storage and computer analysis was developed by Dr. Carl Singer, Marcile Dudley, Ann Kohlstaedt, Ron Van Seventer, Art Buis, David Dee, and Clifford Gammon. Mrs. Betty McKee was extremely helpful in preparing this report.

The Use of Community Parameters Derived from Electrofishing Catches of River Fish as Indicators of Water Quality

J. R. Gammon

Introduction

There is a pronounced need for methods of measuring the effect of various human activities on the aquatic communities of running water ecosystems. Major impacts which lead to an elimination of entire species may be interpreted with little difficulty, but it is unacceptable today to await the disappearance of entire species from an ecosystem in order to assess detrimental environmental effects. Nevertheless, biological investigations too often generate a list of species collected which is supposed to reflect the health of the biological community in itself. Such a list is of value, but its length is strongly dependent upon the effort devoted to its construction and basing a judgement of environmental effects on a comparison of two or more species lists alone is highly inadvisable.

Other methods of gauging environmental effects on biota generally include some quantitative measure of the size of the population, either that of a single group of related organisms or of a single species of special ecological or commercial importance. For example, Larimore and Smith (1963) found the effects of organic pollution on fish populations to be first a reduction in the number of species present, then a reduction in the total weight or biomass, and finally a reduction in the number of individuals. For those working with fish populations in rivers it has become almost automatic to structure studies which use some measure of numeric density as the data base.

Some measure of diversity often is used to characterize the structure of benthic communities (Wilhm and Dorris 1966, 1968), but is not usually employed in work with fish. In a study of fish communities in small streams in Pennsylvania, Denoncourt and Stambaugh (1974) found relatively high species diversities at several sites receiving moderate to heavy pollution and recommended against using diversity indices with fish populations. However, Richards (1976) found diversity indices of value in interpreting faunal changes in the Au Sable River over a 50 year period.

Bechtel and Copeland (1970) found diversity indices based on otter trawl tows to be useful indicators of pollution in Galveston Bay, Texas. McErlean and Mihursky (1969) examined the application of diversity measures to a variety of fish collection data and subsequently applied them to collections in estuaries to demonstrate seasonal changes and annual trends (McErlean, et. al. 1973).

Several years of site-intensive studies in the immediate vicinity of two electrical generating stations located on the middle Wabash River determined that fish moved around predictably in response to varying thermal conditions and were rarely killed directly (Gammon 1971, 1973). However, it was not possible to determine whether the positive and negative behavioral responses reflected long-term changes in the populations or if the fish communities in the immediate vicinity of the electrical generating stations differed significantly from fish communities uninfluenced by thermal inputs. We also needed to determine how much of the river was being influenced by the EGSs. Consequently, a study program was initiated which continued to monitor the fish communities near the two electrical generating stations, but also included studies of flanking reaches of the river.

During 1973 and 1974 the fish communities over 100 miles of the middle Wabash River were examined by repeatedly electrofishing at 24 similar sites, including 4 comparable sites at each EGS (Teppen and Gammon 1976). A majority of species were non-randomly distributed through the 100 miles of river, some more abundant in the lower river, e.g. shortnose gar and bowfin near reproductive bayous, and others more abundant in the upper river, e.g. redhorse which were particularly sensitive to increased temperatures caused by the two EGSs. Other species populations were found to be either more or less common near the EGSs than in flanking regions of the river. The species composition, therefore, shifted considerably in different parts of the river, sometimes in response to natural factors and sometimes because of man-induced changes in water quality.

We also examined five quantitative measures of community structure including (1) relative density (no/km), (2) relative biomass (wt/km), (3) number of species per station, (4) Shannon index of diversity based on numbers, and (5) Shannon index of diversity based on weights. The two Shannon indices were calculated as follows:

$$H = -\sum\left(\frac{n_i}{N}\right) \text{Ln} \left(\frac{n_i}{N}\right)$$

Where n_i = the numbers or weight of individual species in the sample

N = the total number or weight of fish in the sample

All of these community parameters exhibited a common general pattern over the 100 miles of river, but with some interesting anomalies here and there which made interpretation difficult.

In 1975 an additional 100 miles of the upper Wabash River was included in the sampling program and all of the data collected during 1973-75 was analyzed for evenness indices associated with the two Shannon diversity indices and a composite index in addition to the previously mentioned measures of community structure (Gammon 1976). The composite index of well-being (I_{wb}) was calculated according to the formula:

$$I_{wb} = 0.5 \text{ Ln } N + 0.5 \text{ Ln } W + \text{Shannon}_{(no.)} + \text{Shannon}_{(wt.)}$$

where N = the number captured per km
W = the weight captured per km
$\text{Shannon}_{(no.)}$ = Shannon index based on numbers
$\text{Shannon}_{(wt.)}$ = Shannon index based on weights

This composite index combines two widely used indices of diversity and two widely used indices of abundance in approximately equal quantities to form a single composite value reflecting both the diversity and abundance of fish in the collections. It appears to reflect the general "health" of the fish community and, hence, the water quality somewhat more satisfactorily than any single community index or indicator species.

In 1976 a thirty mile segment of the Great Miami River was investigated by this general method as part of a larger effort which attempted to measure the relative impact of two electrical generating stations within a great number of potential impacts (Gammon 1977). In 1977, 130 miles of the Wabash River were again studied and demonstrated some interesting contrasts to the 1973-75 study. It is the intent of this paper to examine and evaluate the findings of this community structure approach as applied to the Wabash and Great Miami Rivers.

The Rivers and Methods

The Great Miami River

The Miami River Valley from Dayton to the Ohio River is thickly settled and heavily industrialized. The river at Dayton, Ohio drains 6,508 km^2 (2,513 mi^2) of land and has a flow which averages 2,206 cfs. (Todd 1970). Weston (1967) has detailed the uses and polluted state of the river.

Seventeen collecting stations were established on the river and two each on the lower portions of the Mad and Stillwater Rivers (Figure 1). Each station was located on the outside of gradual bends in the river and were about 0.33 km long as measured with a Lietz optical rangefinder. A series of dams created lentic-like habitats and also blocked upstream movements of fish, including the Steele Dam (River Mile 81.3), Tait Dam (RM 76.6), Hutchings Dam (RM 63.5), and Chautauqua Dam (RM 61.6).

Each month from June through September, 1976 fish were collected from each station using a battery-powered 600 VDC electrofishing unit. When depth and discharge permitted each station was electrofished from upstream to downstream by wading, otherwise a 12' boat containing the electrofishing unit and two personnel was moved slowly near shore over the measured distance.

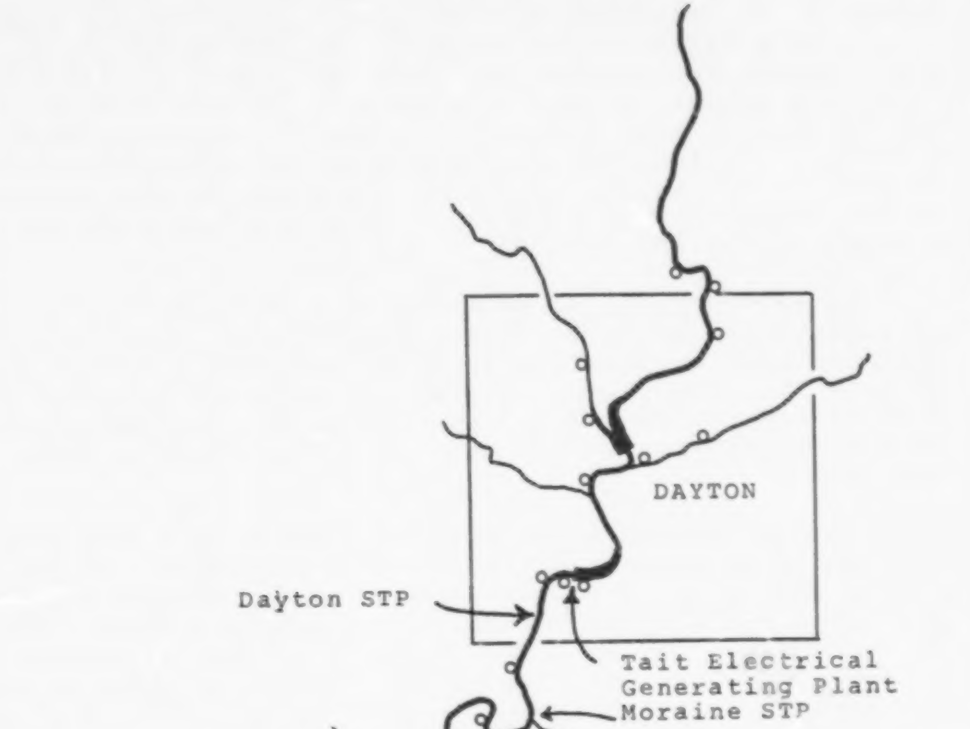

DAYTON
Dayton STP
Tait Electrical Generating Plant
Moraine STP
WEST CARROLLTON
W. Carrollton STP
MIAMIBURG
Miamiburg STP
Hutchings Electrical Generating Plant
FRANKLIN
Franklin STP
MIDDLETOWN

Figure 1: Location of sampling stations in relation to sewage treatment effluents and electric generating stations.

The Wabash River

The Wabash River at Terre Haute drains 31,598 km^2 (12,200 mi^2) and has an average discharge of 10,200 cfs. (Todd 1970). Although several large flood control reservoirs have been constructed on tributaries, the Wabash River itself flows freely in response to changing weather conditions. Turbidity is generally high because of silt during high discharge and because of high densities of diatoms during summer. Water quality is influenced importantly by extensive agriculture throughout the basin, by coal strip mines in the southern part of the drainage basin, and by discharges from municipalities and industries (Figure 2).

In 1977 a total of 47 collecting stations were established throughout 145 miles of river, including 8 stations at the Cayuga Electrical Generating Station (EGS) and 6 at the Wabash EGS (Figure 2). Each sampling station consisted of a 0.5 km section of outside bend as measured with a Lietz rangefinder. Many stations were in the same locations used in 1973, 1974, and 1975.

The collecting apparatus consisted of a Smith-Root Type VI electrofisher powered by a 3000 watt generator. Pulse configuration consisted of a triangular wave interrupted into 60 pps and producing 400-600 VDC at approximately 5 amps. The pulsed DC current was fed into an electrode system consisting of two circlets of short stainless-steel anodes extended by booms approximately 8 feet off the bow of a 16 foot John boat and two gangs of long woven copper cathodes weighed at the ends and suspended from port and starboard gunwales near the bow.

The basic procedure for collecting was to begin at the upstream boundary and slowly electrofish downstream as close to shore and cover as possible to the end of the station. Stations were electrofished sequentially from up-river to down-river until all had been visited, usually within a 4-6 day period.

Following each collecting run fish were identified to species, weighed, and measured and then returned unharmed to the river. All data was recorded on magnetic tape and disc and then analyzed.

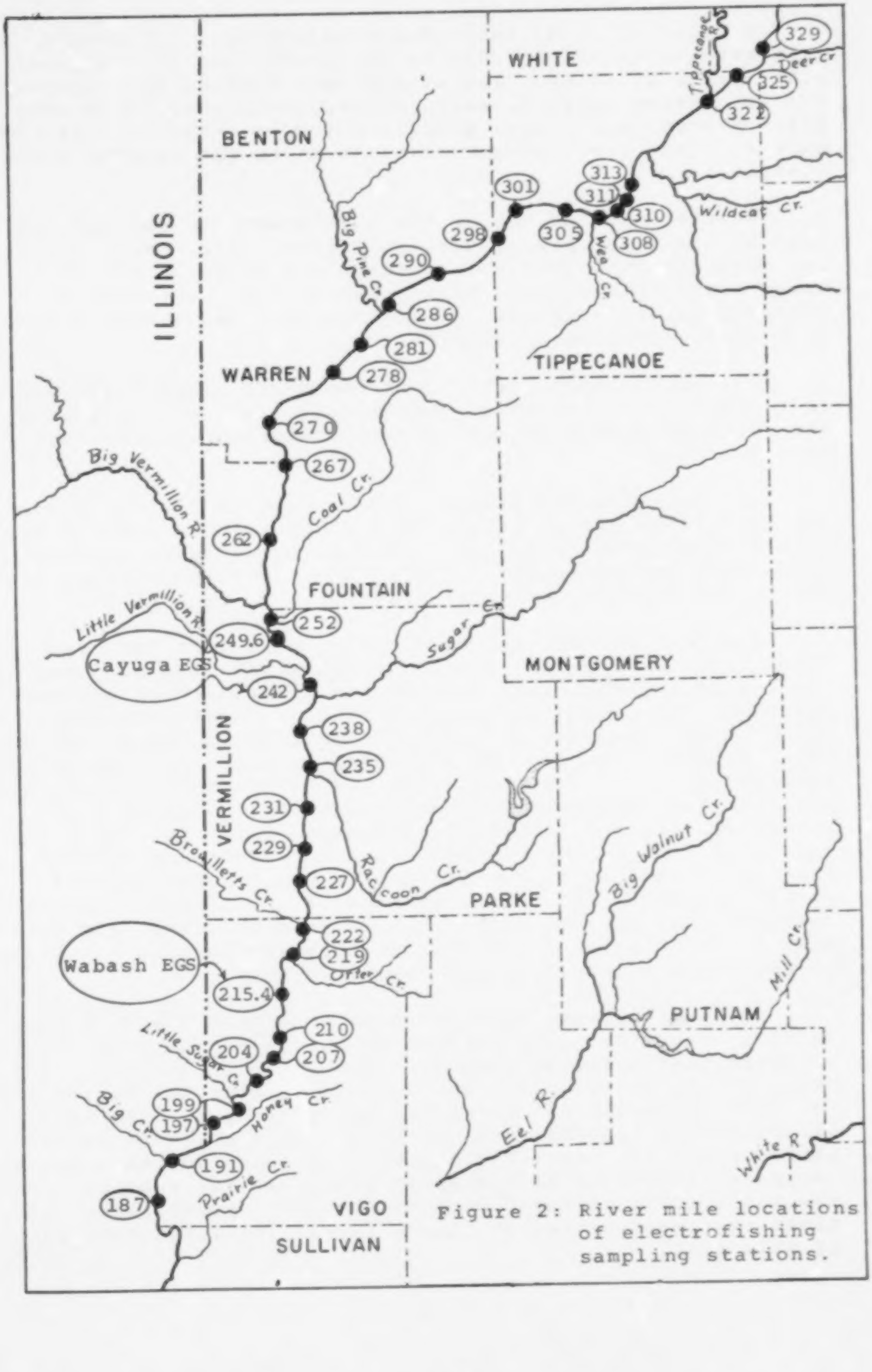

WHITE
BENTON
ILLINOIS
WARREN
TIPPECANOE
FOUNTAIN
MONTGOMERY
VERMILLION
PARKE
PUTNAM
VIGO
SULLIVAN
Tippecanoe R.
Deer Cr.
Wildcat Cr.
Wea Cr.
Big Pine Cr.
Big Vermillion R.
Coal Cr.
Little Vermillion R.
Sugar Cr.
Raccoon Cr.
Brouilletts Cr.
Otter Cr.
Big Walnut Cr.
Mill Cr.
Eel R.
White R.
Little Sugar Cr.
Honey Cr.
Big Cr.
Prairie Cr.
Cayuga EGS
Wabash EGS
329
325
322
313
311
310
308
305
301
298
290
286
281
278
270
267
262
252
249.6
242
238
235
231
229
227
222
219
215.4
210
207
204
199
197
191
187

Figure 2: River mile locations of electrofishing sampling stations.

Results - The Great Miami River

A total of 2,545 individuals belonging to 40 species of fish were collected in 1976 by electrofishing over a total distance of 27.24 km. The most common species were longear sunfish, green sunfish, carp, stoneroller, smallmouth bass, gizzard shad, rock bass, goldfish, golden redhorse, and hog sucker, which together comprised 76.4% of the numeric catch (Table 1).

However, the nature of the fish community changed markedly as the river passes through Dayton, Ohio. The largest and most diversified fish community was found in the Stillwater River (Figure 3). This community was dominated by hog suckers, golden redhorse, spotted sucker, smallmouth bass, rock bass, and longear sunfish.

The upper three stations of the Great Miami River were also supportive of a large, relatively diverse fish community although rock bass were scarce and green sunfish much more abundant.

The fish community in the lower part of the Mad River was of a different character than anywhere else and was dominated by stonerollers with a scattering of other species. Industrial effluents above and in this reach may affect the biotic composition, as noted previously by Conn (1972).

The fish communities in the Dayton Pool of the Great Miami River between the Steele and Tait Dams (RM 81.3 and RM 76.6) were somewhat less diverse and numerous than upriver stations. This section appeared to be severely stressed prior to the June sampling period and then improved throughout the summer despite falling water levels. The community immediately below the Steele Dam was always more diverse and numerous than stations further downstream. Gizzard shad, golden shiner, and largemouth bass were far more common in this pool than anywhere else. Species which were reduced in abundance compared to further upstream sections included smallmouth bass, rock bass, green sunfish, bluegill, golden redhorse, and spotted sucker. White sucker, carp, and goldfish - all of which are pollution tolerant species - increased in abundance compared to upstream stations.

The pool between Tait and Hutchings Dams (RM 76.6 and RM 63.5) contained fish communities very similar qualitatively to those just upstream although much lower in density. However, in the section of river downstream from the Dayton STP the fish community consisted primarily of carp, goldfish, carp/goldfish hybrids, and, in certain areas, white suckers. Not only was the catch reduced to only about 40 individuals/km (compared to 150/km in the upper stations, for example), but the individuals captured were often small, young fish. At times it appeared that no fish whatever inhibited some parts of this pool.

Table 1: Number of fish captured by electrofishing in 1976 in several sections of the Great Miami River and its main tributaries.

Species	Mad River	Still-water River	Great Miami River Above Dayton	In Dayton	Dayton STP to Chautauqua Dam	Chautauque Dam to Middletown
Gizzard shad	10	4	16	110	2	1
Grass pickerel	-	-	-	-	-	1
Hog sucker	11	52	4	28	3	3
White sucker	9	2	12	22	28	2
Golden redhorse	1	42	29	29	-	1
Black redhorse	-	-	1	4	-	-
Silver redhorse	-	2	-	-	-	-
Shorthead redhorse	-	2	1	4	-	-
Spotted sucker	4	19	12	5	-	-
Quillback	-	-	-	3	-	-
Carp	10	9	9	24	125	53
Goldfish	-	-	-	28	69	32
Carp/Goldfish hybrids	-	-	-	2	4	2
Golden shiner	1	10	33	47	4	1
Striped shiner	4	2	2	1	-	4
Spotfin shiner	4	3	23	9	5	24
Silver shiner	7	2	1	8	1	1
Mimic shiner	-	-	1	-	-	-
Emerald shiner	-	-	-	2	-	-
Creek chub	-	2	-	2	7	-
Stoneroller	127	6	2	28	6	-
Bluntnose minnows	6	5	30	32	6	-
Fathead minnow	-	-	5	2	-	-
Suckermouth minnow	-	-	-	3	-	-
Channel catfish	-	-	-	1	-	-
Yellow bullhead	-	-	1	-	1	-
Stonecat	1	1	-	-	-	-

Table 1: continued

			Great Miami River			
Species	Mad River	Still-water River	Above Dayton	In Dayton	Dayton STP to Chautauqua Dam	Chautauque Dam to Middletown
Smallmouth bass	13	48	54	41	5	3
Largemouth bass	-	3	2	10	2	-
Rock bass	9	79	14	21	3	3
Warmouth	-	3	-	3	-	1
Longear sunfish	6	154	169	106	19	28
Orangespot sunfish	-	1	3	10	1	1
Green sunfish	16	54	118	63	18	27
Pumpkinseed	-	-	-	2	-	-
Bluegill	-	15	33	15	5	6
Black crappie	-	-	2	-	-	-
White crappie	-	-	-	7	-	-
Log perch	-	4	5	2	-	-
Greenside darter	2	2	-	4	-	-
Banded darter	-	-	-	1	-	-
No. collecting stations	2	2	3	5	6	3
Total distance electrofished-Km	2.28	2.48	3.84	7.08	7.92	3.64
Total no. fish	241	526	582	688	314	194
Mean No./Km.	105.7	212.1	151.6	97.2	39.6	53.3
No. of species	18	26	26	35	20	19

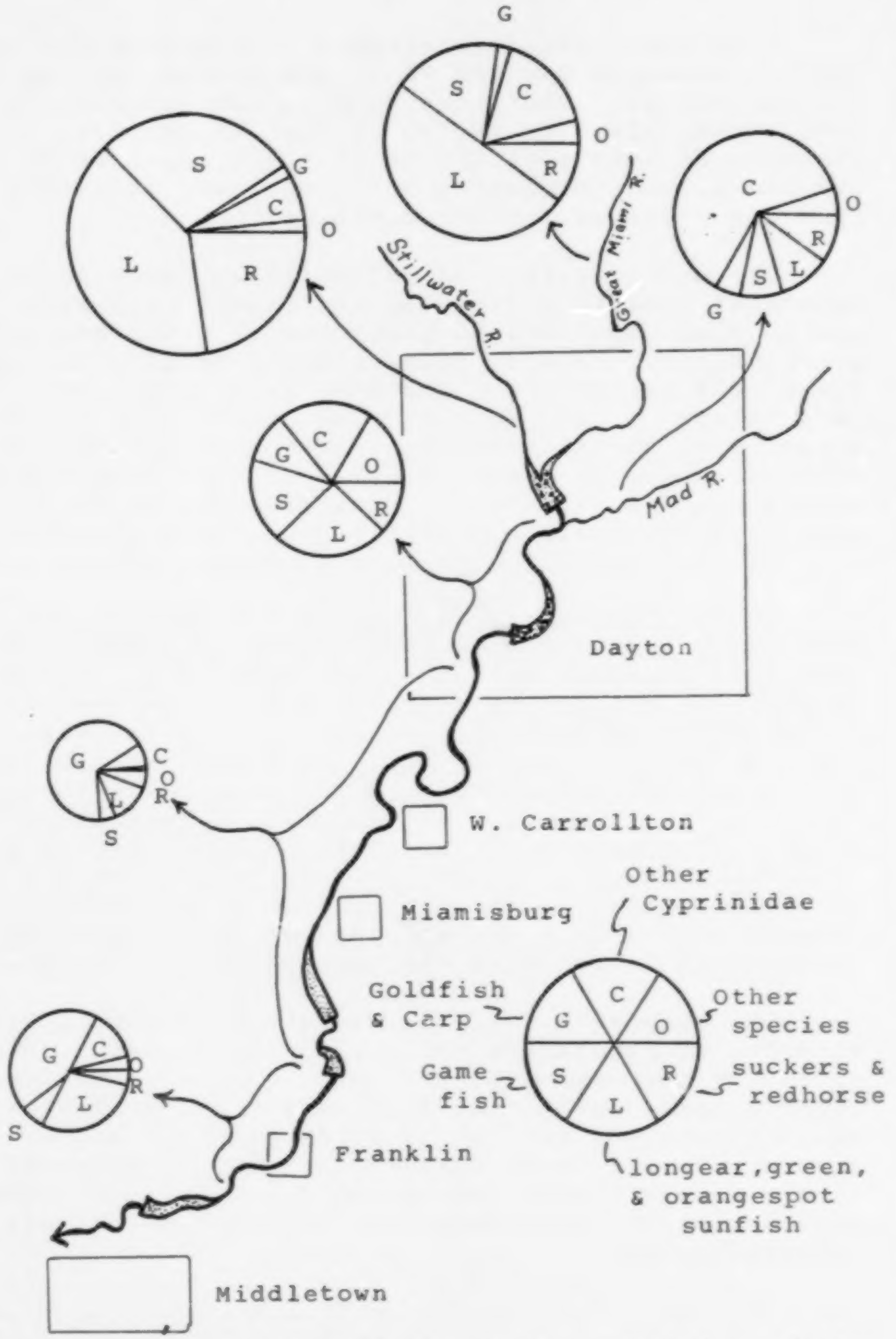

G
S
C
O
L
R
Great Miami R.
Stillwater R.
C
O
R
L
S
G
G
S
C
G
O
S
R
L
Mad R.
Dayton
G
C
O
R
L
S
W. Carrollton
Miamisburg
Other Cyprinidae
Goldfish & Carp
Other species
Game fish
suckers & redhorse
longear, green, & orangespot sunfish
G
C
O
S
L
R
G
C
O
R
L
S
Franklin
Middletown

Figure 3: Composition of the fish communities of the Great Miami River system. The area of each circle is proportional to the relative density (no/km).

The fish community in the pool between Hutchings Dam (RM 63.5) and Chautaugua Dam (RM 61.7) was similar to those above the former, consisting principally of carp and goldfish with a small scattering of other species.

Carp and goldfish continued to dominate the community between Chautauqua Dam (RM 61.7) and Middletown Dam (RM 55.8), but longear sunfish, green sunfish and spotfin shiner also become common elements in the catch. In the last collecting stations in this pool (RM 58.0) there appeared to be a numerous and diverse community which probably indicated a recovery from the stresses further upstream.

The major sources of pollution appeared to be the waste treatment effluents from Dayton, Miamisburg, West Carrollton, and Moraine, the organic particles of which settled out in pools causing a steady production of bubbles throughout the summer and early fall. The dissolved oxygen concentrations fell to lows of 2.0 mg/l and less each month of the study as measured by the Miamisburg A water quality monitor of the Miami Conservancy District at RM 65.75. Numerous other effluents bearing a variety of industrial wastes to the Great Miami River and two small electrical generating stations are also present, but the major problem is of an organic nature.

Such a stressed system where the impacts are large and clearcut provides a good opportunity to examine the community structure approach as a tool of evaluation. As would be expected, the trends exhibited by all of the community indices reflected the altered fish communities with relatively high numbers, biomass, and diversities characterizing the communities upstream from Dayton and low values for the communities below Dayton (Figures 4 , 5 , and 6). A similar pattern is exhibited by the mean weight of fish (excluding carp and goldfish) with means of 60-120 g in upstream stations and 10-30 g in environmentally degraded sections. The combined local influence of the Tait EGS and dam causes a brief decrease in biomass and an increase in the two Shannon diversities.

The composite index of well-being brings together these elements to regularize the basic pattern which shows, in addition to the community extremes, a zone of intermediate character within Dayton (RM 75 to RM 80) and a zone of recovery below Chautauqua Dam (RM 57 to RM 62) (Figure 7). The standard errors were much smaller both in the upstream zones and in the recovery area indicating a comparative stability of the environment in these segments compared to the more unstable, impacted areas.

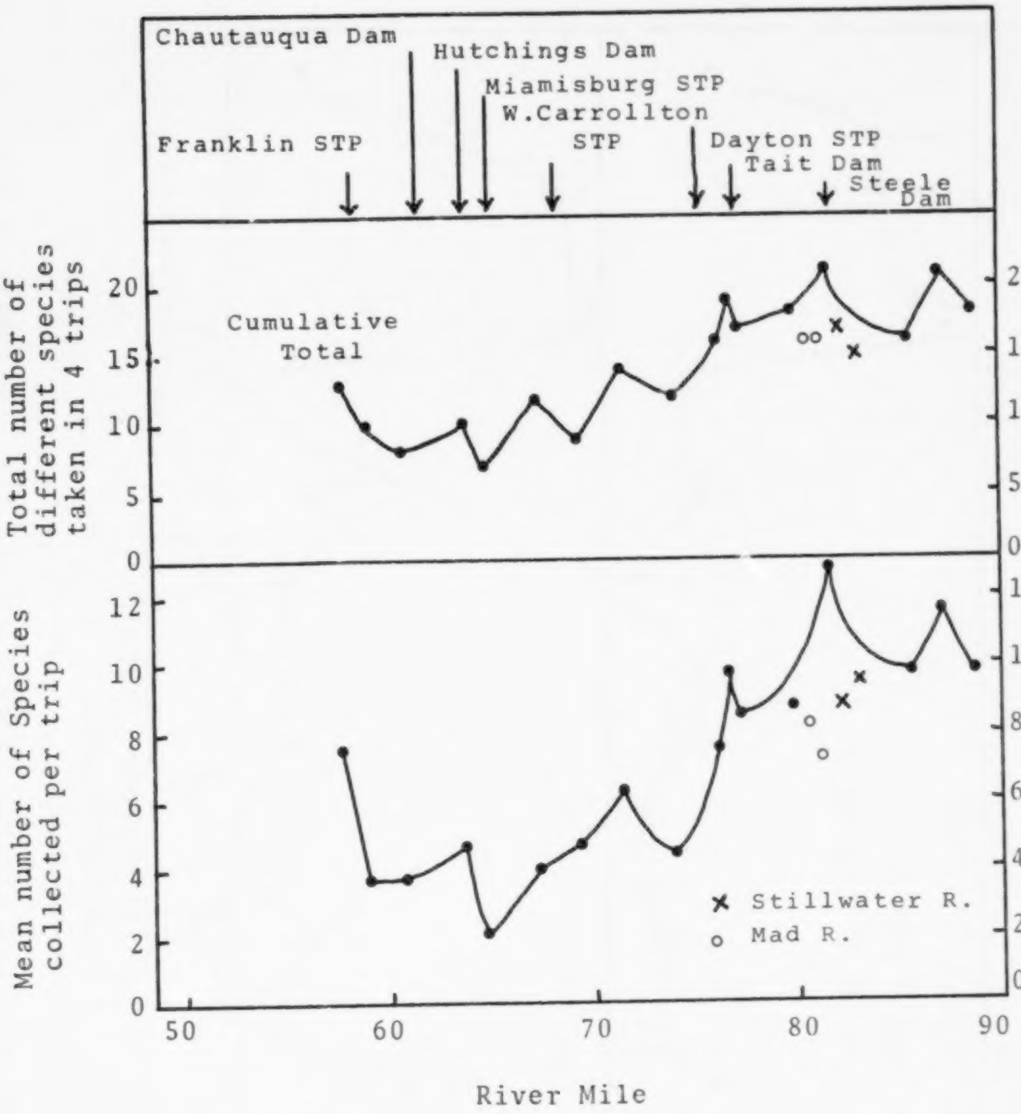


Figure 4: The mean number of species of fish collected per trip and the total number collected in four trips in The Great Miami, Mad, and Stillwater Rivers.

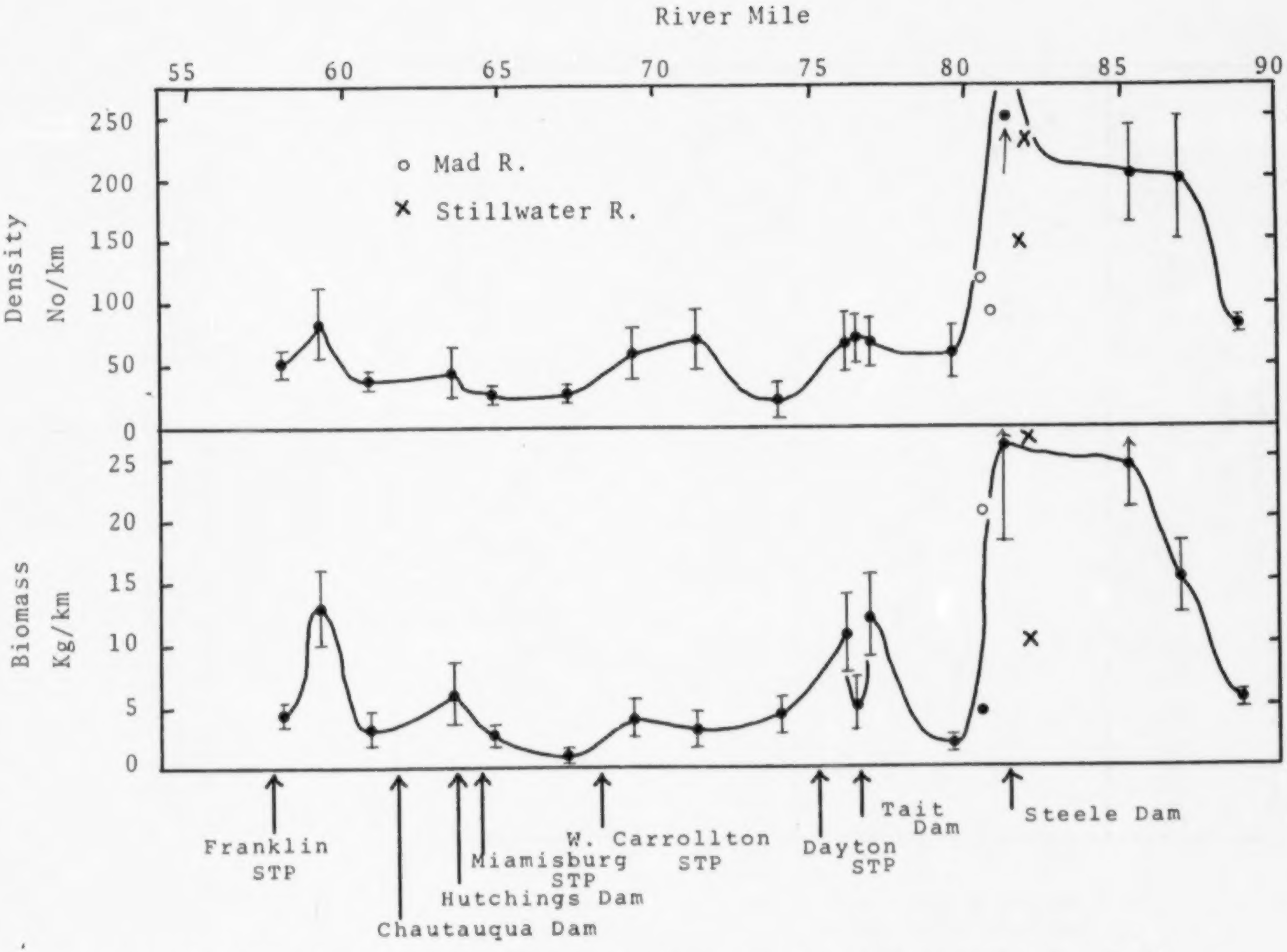


Figure 5: Relative density and biomass profile of the fish community of the Great Miami R. and tributaries. Based on four collections June - September, 1976 (mean ± 1 S.E.)

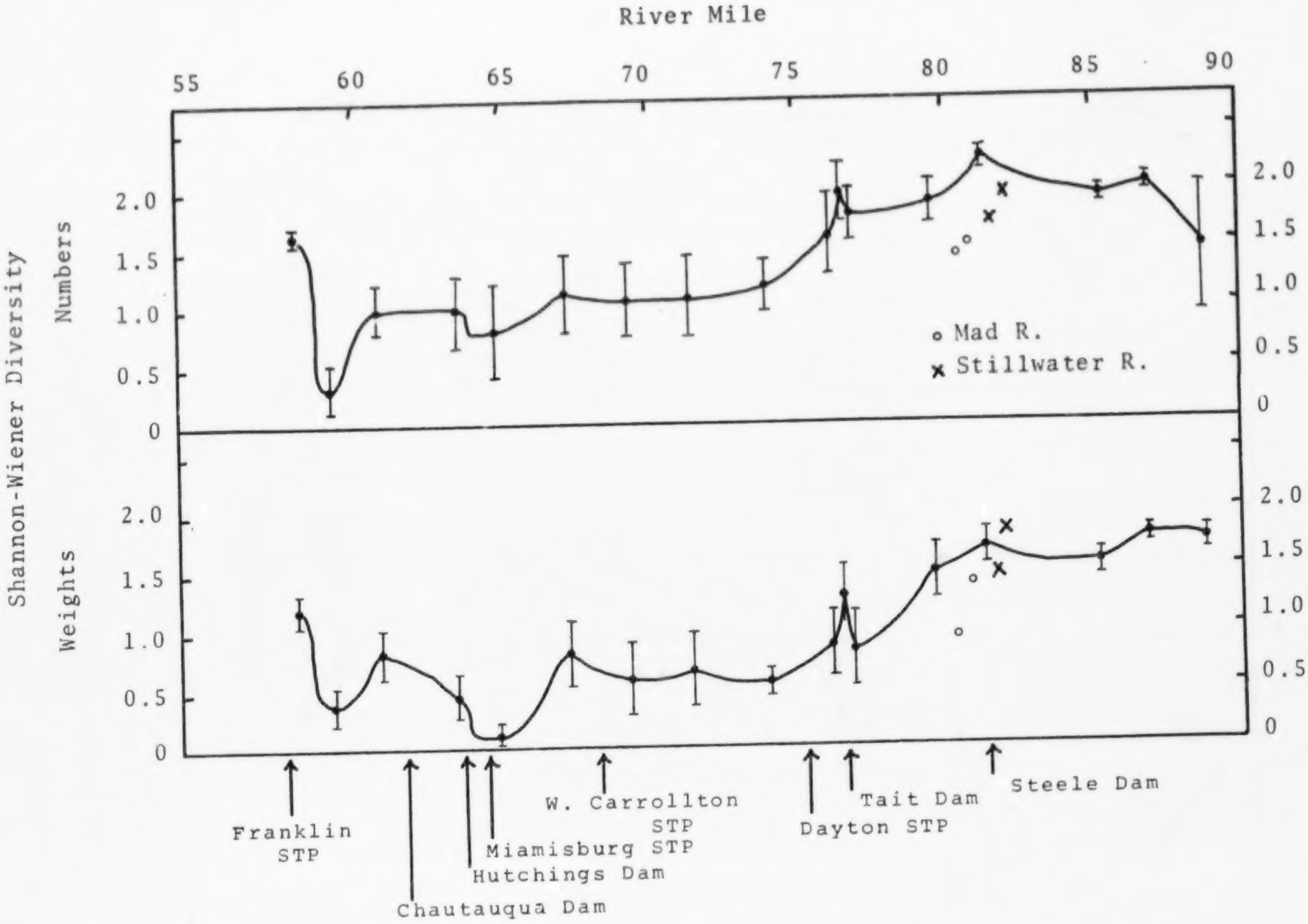


Figure 6: Shannon-Wiener indices of diversity (numbers and weights) for fish collections of the Great Miami R. and tributaries. Based on four collections June - September, 1976. (mean ± 1 S.E.)

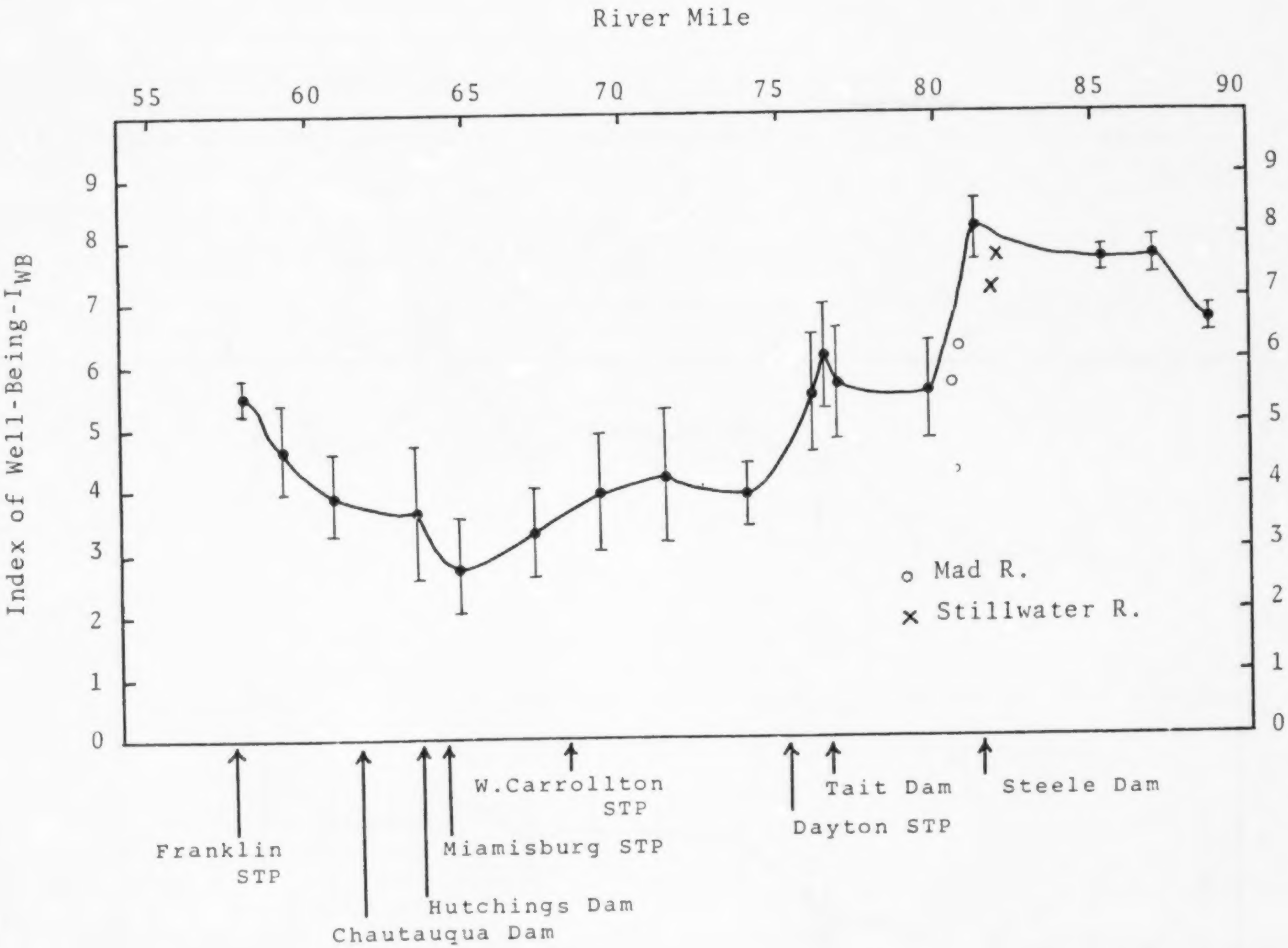


Figure 7: Composite Index profile of fish community of the Great Miami R. and tributaries. Based on four collections June - September, 1976. (mean ± 1 S.E.).

Results - The Wabash River

The analyses of the fish communities in the Wabash River are based upon 7,120 individuals of 57 species captured during the period 1973-75 and 3,795 individuals of 51 species captured in 1977 (Table 2).

The character of the fish communities in the Wabash River also changes from place to place. As illustrated by the 1975 data (Figure 8) upriver from Lafayette the community is dominated by redhorse, hog sucker, carpsucker, and carp. The various species of sportfish, although more common here than elsewhere, make up a relatively small part of the catch. Downstream from Lafayette gizzard shad and carp dominate the catch while carpsuckers and redhorse diminish in importance. Flathead catfish, which have been shown to be stimulated by the thermal inputs, become common downstream from Cayuga EGS.

The various community parameters generated from electrofishing data exhibited patterns which declined from upstream to downstream, but with a good deal more "noise" than with the Great Miami River data. Only the composite index is included here (Figure 9), but all of the community parameters exhibited the same basic pattern (Gammon 1976). Some annual variations occurred primarily in relation to summer discharge, but generally regional variations were greater than temporal variations.

The range of I_{wb} values is less extreme, but of the same magnitude as those obtained in the Great Miami River study. High values from 7.0 to 8.0 were found upstream from Lafayette (RM 310). A general, erratic decline occurred from Lafayette to Cayuga (RM 250 to RM 310), then a low plateau from Cayuga to Wabash EGS (RM 215 to RM 250). A brief recovery is indicated in the immediate vicinity of Terre Haute and then another decline occurred downstream from Terre Haute (RM 185 to RM 200).

Between 1975 and 1977 there appeared to be a rather significant improvement downstream from Lafayette. The reach of river between the two EGSs was found to have the poorest fish communities during the 1973-75 period with I_{wb} values around 5.0 - 5.5. In 1977 the I_{wb} values declined even further to 4.0 - 5.0. This decline in the composite index was indicative of worsened environmental conditions. Immediately following the last series of collections in mid July 1977 this section of river developed severe problems with low dissolved oxygen concentration (Gammon and Riedy, 1980). Thus, the fish community showed by its abundance and diversity that unfavorable environmental conditions were present in this segment long before any stress was detected by chemical means.

Table 2: Aggregate electrofishing catch of fish in 145 miles of the Wabash River during 1977.

NAME	# CT.	% CT.	WT. (KG)	% WT.
Silvery Lamprey	17	0.44	0.19	0.00
Shlnse. Sturgeon	9	0.23	11.57	0.49
Paddlefish	1	0.02	1.70	0.07
Bowfin	13	0.34	16.89	0.72
Longnose Gar	52	1.37	26.30	1.13
Shortnose Gar	60	1.58	31.64	1.35
Gizzard Shad	1704	44.90	325.72	13.99
Skipjack Herring	13	0.34	1.75	0.07
Goldeye	37	0.97	16.59	0.71
Mooneye	26	0.68	7.71	0.33
Yellow Bullhead	1	0.02	0.37	0.01
Channel Catfish	39	0.02	23.73	1.01
Flathead Catfish	135	3.55	59.59	2.56
American Eel	9	0.23	4.64	0.19
White Perch	2	0.05	0.31	0.01
White Bass	60	1.58	10.90	0.46
Freshwater Drum	57	1.50	37.67	1.61
+Carp	586	15.44	1115.24	47.91
Goldfish+Carp Hy	1	0.02	1.00	0.04
Qback Carpsucker	6	0.15	2.16	0.09
White Sucker	2	0.05	1.18	0.05
Nrthrn. Hogsucker	60	1.58	17.62	0.75
Bigmouth Buffalo	9	0.23	24.27	1.04
Spotted Sucker	1	0.02	0.59	0.02
Silver Redhorse	58	1.52	56.47	2.42
Black Redhorse	4	0.10	2.38	0.10
Golden Redhorse	118	3.10	89.09	3.82
Shorthd. Redhorse	184	4.84	122.63	5.26
River Redhorse	10	0.47	22.56	0.96
N. Riv. Carpsucker	205	5.40	142.52	6.12
Hifin Carpsucker	6	0.15	3.15	0.13
Blue Sucker	17	0.44	35.47	1.52
Smallmth. Buffalo	20	0.52	52.32	2.24
Black Buffalo	3	0.07	8.29	0.35
Emerald Shiner	11	0.29	0.16	0.00
Spotfin Shiner	19	0.50	0.15	0.00
Creek Chub	8	0.21	0.15	0.00
Silvery Minnow	6	0.15	0.11	0.00
River Chub	1	0.02	0.00	0.00
Rockbass	5	0.13	0.84	0.03
Bluegill	3	0.07	0.23	0.01
Longear Sunfish	105	2.76	4.60	0.19
Smallmouth Bass	15	0.39	5.46	0.23
Largemouth Bass	1	0.02	0.21	0.00
White Crappie	12	0.31	1.70	0.07
Black Crappie	1	0.02	0.17	0.00
Spotted Bass	21	0.55	3.49	0.15
Redear Sunfish	1	0.02	0.02	0.00
Greenside Darter	1	0.02	0.00	0.00
Logperch	2	0.05	0.05	0.00
Sauger	50	1.31	35.95	1.54

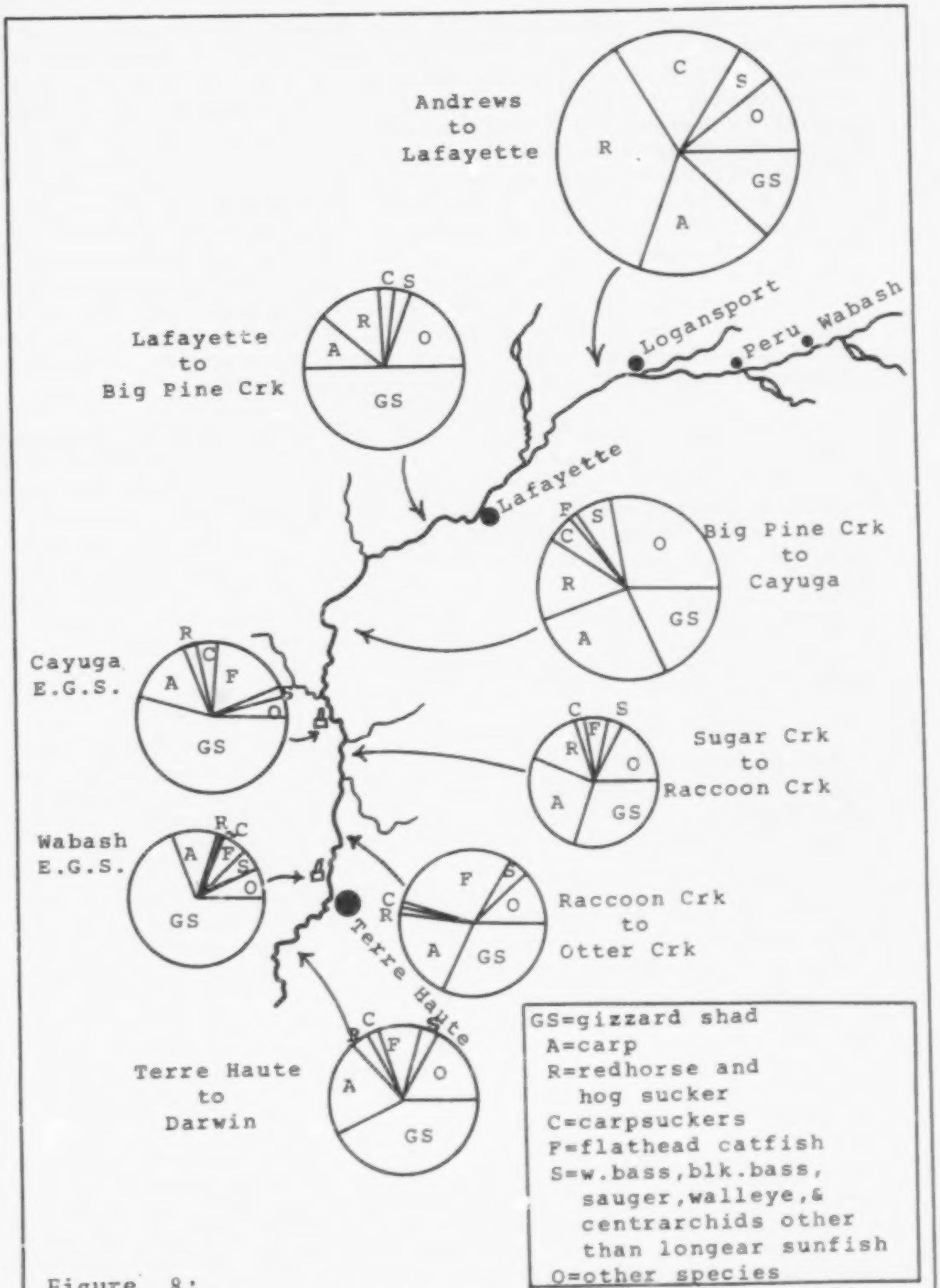

Andrews to Lafayette
R
C
S
O
GS
A
Logansport
Peru
Wabash
Lafayette to Big Pine Crk
C S
R
A
O
GS
Lafayette
Big Pine Crk to Cayuga
F
S
C
O
R
GS
A
Cayuga E.G.S.
R
C
A
F
S
O
GS
Sugar Crk to Raccoon Crk
C S
F
R
O
A
GS
Wabash E.G.S.
R C
A
F
S
O
GS
Raccoon Crk to Otter Crk
F
S
C
R
O
A
GS
Terre Haute
Terre Haute to Darwin
R
C
F
S
A
O
GS
GS=gizzard shad
A=carp
R=redhorse and hog sucker
C=carpsuckers
F=flathead catfish
S=w.bass,blk.bass, sauger,walleye,& centrarchids other than longear sunfish
O=other species

Figure 8:
Composition of the electrofishing catch during 1975 in designated segments of the Wabash River. The area of the circle is proportional to the mean No/Km. (Gammon, 1976)

Discussion

The fish communities of the Wabash River and the Great Miami River are formed from the same species with some exceptions. These communities respond to various environmental stresses by reorganizations in species composition. Where stress is large, as in the Great Miami River below Dayton, Ohio, the community composition shifts toward obviously pollution tolerant species of fish. However, where stress is small and/or diffuse, as in most of the Wabash River and in the Great Miami River at Dayton, the shift in species composition, if present at all, is too subtle to detect with assurance. It appears that different indices of community structure may provide a means of detecting subtle shifts in stressed communities and that a blend of different indices, as for example the composite index, may serve to magnify and clarify the community response to subtle perturbations.

A composite index may also act as a normalizer, permitting comparisons of different rivers as well as different sections of river. In the Great Miami River good sections of stream yielded catches whose community parameters were 150/km, 20 kg/km, and Shannon indices of 1.5 to 2.0, while poor sections yielded catches less than 50/km, 5 kg/km, and Shannon indices of 0.8 to 1.2. Fewer, but larger, fish were taken in the Wabash River, but Shannon diversities tended to be similar to those from the Great Miami River communities. Table 3 summarizes the community parameters from good and poor sections of both rivers and an intermediate value for each parameter.

Of special interest is the fact that, although there are differences in relative density and relative biomass, the composite indices are very similar for good, intermediate, and poor communities in the two rivers, approximately 7.5 for good communities, 6.25 for intermediate communities, and 5.0 for poor communities. Using these values to delineate environmental conditions of these rivers, values exceeding 7.5 appear to reflect a good environment, a fair environment is indicated when values are 6.25 to 7.5, a poor environment from 5.0 to 6.25, and a degraded environment when values fall below 5.0.

Applying this criteria to the composite index profiles for the two rivers helps clarify and interpret the results of studies of this kind. The deteriorating environmental conditions in the Wabash River between Cayuga and Wabash EGSs is indicated by a decline in I_{wb} values from the poor interval in 1973-75 to the degraded interval in 1977 (Figure 10). Using this criterion for the Great Miami River profile the 15 mile segment from the Dayton STP to Franklin, Ohio is clearly degraded, the lower Mad River and the short portion of main river in downtown Dayton is poor, and the upper section of river as well as the Stillwater River would be classified as good (Figure 11).

It may be that this kind of approach may be of value for other rivers of this kind. Would that there were clean rivers in the midwest which could be used as a comparison for the majority. In the absence of such desirable waters and taking the optimistic view that some rivers may become less polluted and environmentally upgraded, this community structure approach may be useful in gauging progress toward the desired goal.

Table 3: Community values delineating good, intermediate, and poor fish communities in the Wabash and Great Miami Rivers.

Parameter	Great Miami River			Wabash River		
	Good	Intermed.	Poor	Good	Intermed.	Poor
No/km	150	100	50	60	45	30
Kg/km	20	10	5	50	35	20
Shannon-no.	2.0	1.6	1.2	1.8	1.4	1.0
Shannon-wt.	1.5	1.1	0.8	1.8	1.4	1.0
I_{wb}	7.5	6.15	4.76	7.60	6.48	5.20

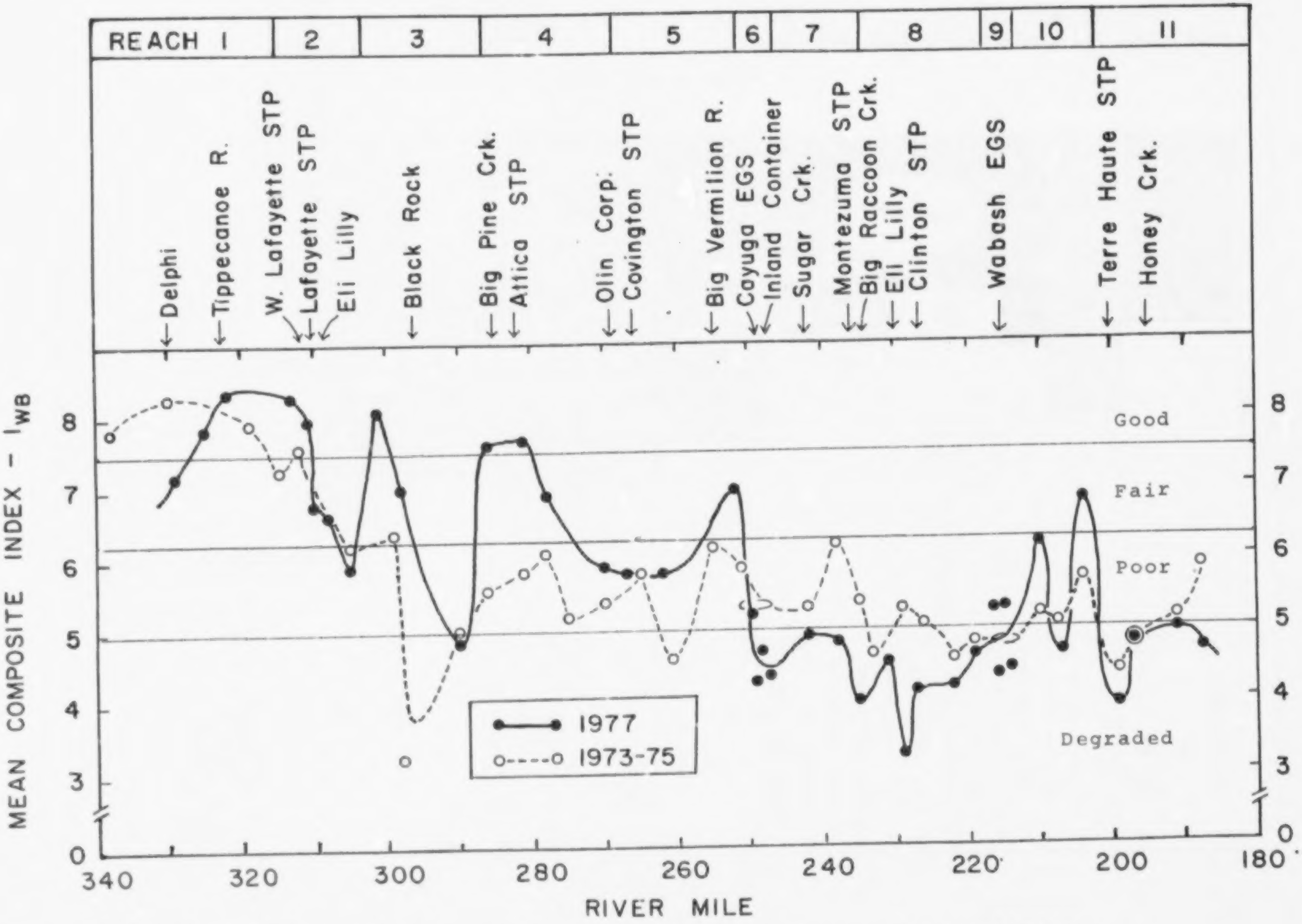


Figure 9: The composite index as it reflects environmental conditions of the Wabash River in 1973-75 and 1977.

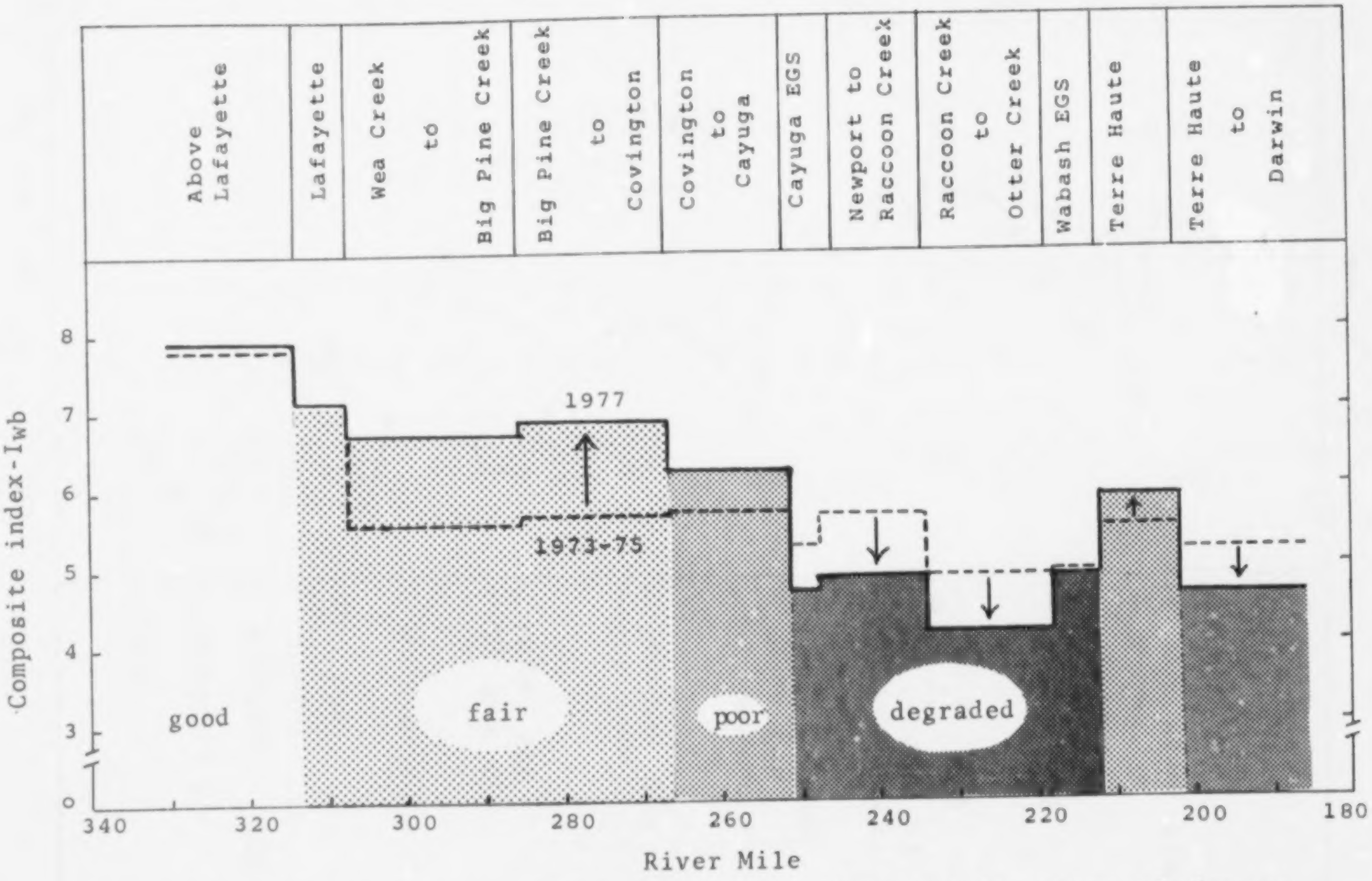


Figure 10: Schematic representation of the magnitude and direction of changes in the mean composite index values in 11 segments of the Wabash River from 1973-75 to 1977.

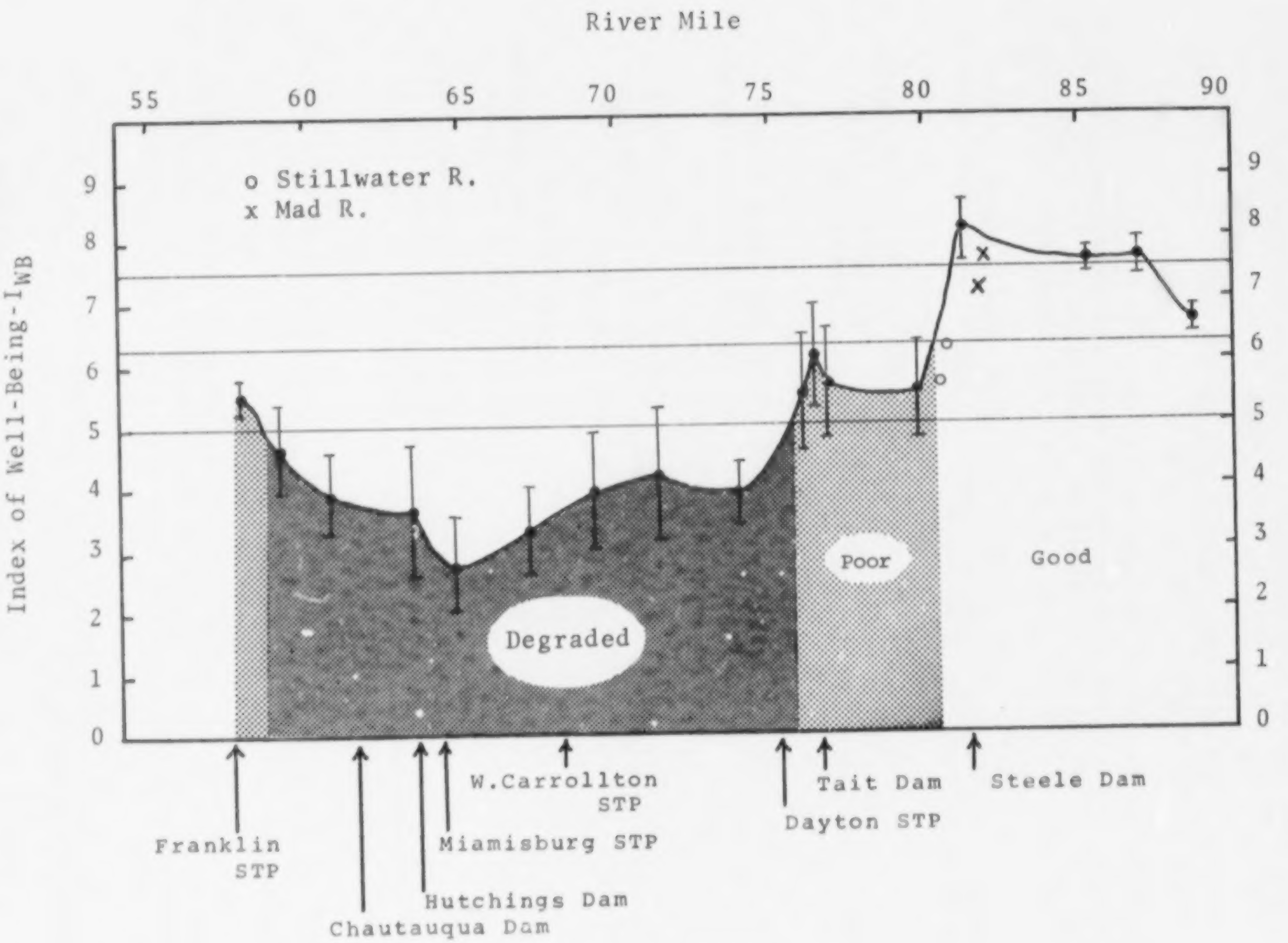


Figure 11:The composite index as it reflects environmental conditions of the Great Miami River in 1976.

References

Bechtel, T. J. and B. J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Cont. Mar. Sci., 15:103-132.

Conn, C. C. 1972. Biological survey of the Mad River. Miami Cons. Dist. Report. 21 pp. mimeo.

Denoncourt, R. F. and J. W. Stambaugh, Jr. 1974. An ichthyofaunal survey and discussion of fish species diversity as an indicator of water quality, Codorus Creek drainage, York County, Pennsylvania. Proc. Pa. Acad. Sci. 48:71-78.

Gammon, J. R. 1971. The response of fish populations in the Wabash River to heated effluents. Proc. Third Nat. Symp. Radioecology, Vol. 1:513-523.

Gammon, J. R. 1973. The effect of thermal inputs on the populations of fish macroinvertebrates in the Wabash River. Water Res. Res. Center, Purdue U., Tech. Report No. 32:105 pp.

Gammon, J. R. 1977. The fish community of the Great Miami River near Dayton, Ohio. Report to Dayton Power and Light Co., Dayton, Ohio. 52 pp. mimeo.

Gammon, J. R. and J. M. Reidy. 1980. The role of tributaries during an episode of low dissolved oxygen in the Wabash River. Warmwater Streams Symposium. In press

McErlean, A. J., S. G. O'Connor, J. A. Mihursky, and C. I. Gibson. 1973. Abundance, diversity and seasonal patterns of estuarine fish populations. Est. & Coastal Mar. Sci. I.

McErlean, A. J. and J. A. Mihursky. 1969. Species diversity-species abundance of fish populations: an examination of various methods. Proc. 22nd Ann. Conf. So. Coast Assoc. Game & Fish Comm.:367-372.

Richards, J. S. 1976. Changes in fish species composition in the Au Sable River, Michigan from the 1920's to 1972. Trans. Am. Fish. Soc. 105(1):32-40.

Teppen, T. C. and J. R. Gammon. 1976. Distribution and abundance of fish populations in the middle Wabash River. Thermal Ecology II (ERDA Symp. Series) CONF - 75-425: 272-283.

Todd, D. K. 1970. The water encyclopedia. Water Inf. Center, Port Washington, N.Y. 559 pp.

Wilhm, J. L. and T. C. Dorris. 1966. Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. Am Midl. [redacted]76:427-449.

Wilhm, J. L. and T. C. Dorris. 1968. Biological parameters for water quality criteria. Bioscience 18:477-481.

BIOTIC IMPACT OF ORGANIC AND INORGANIC SEDIMENTS

J.K. BLAND
Project Officer
Water Quality Management Branch
United States Environmental
  Protection Agency

Introduction

For the past two years I have functioned as a 208 program project officer in the Ohio Water Quality Management Section of United States Environmental Protection Agency (USEPA). Prior to that time I was an environmental educator at the Field Museum of Natural History and was involved in several years of stream related work. During this period I have the followed the development of 208 water quality management initiatives in several cities and states and have had a continual concern about the infusion of biological objectives into those programs. From my perspective we seem to be inordinately concerned about water quality from a chemical standpoint to the detriment of clearly articulated biological goals and monitoring. Most resource managers wouldn't think of grading the "quality" of a prairie by its soil chemistries yet streams are continually "graded" and managed largely on the basis of in-stream chemistries and waste load allocations. We don't deny the need for such chemical measurements but feel that we have been spending a great deal of time gauging the "baby's bathwater" without looking at how the baby itself is doing. Furthermore, in-stream chemical standards have too frequently been developed on a state wide basis without recognition of the biogeographical distinctions necessary to give resolution to the standard setting process. In Region V I know of only one State, Illinois (James Park, Illinois Environmental Proteciton Agency personal communication), which is developing a biologically based hierarchy with which to generate stream use-classifications.

Gauging Biological Responses

Institution of a set of management practices is based on the assumption that the causal events of the system under study are known, that the major determinants of the system are susceptible to management, and that the effects of management will not be obscured by contingencies. If a set of "best management practices"is to be determined, it is necessary to have specific goals for the response of the system/watershed being managed. This is difficult because various schools of biologists have different concepts of what represents biological integrity in a stream. The stated goal of the Clean Water Act of fishable, swimable, waters is too broadly stated to be meaningful in actually judging the performance of a set of best management practices within a watershed. Several recent monographs published by USEPA have dealt with the problem of establishing a conceptual framework for setting management goals for watersheds (cf. "Toward a Classification for Watershed Management and Stream Protection" C. Warren, 1979, U.S.E.P.A.-600-79-059; and "Impacts of Sediment and Nutrients on Biota in Surface Waters of the United States." Farnsworth, et.al, EPA-600/3-79-105). Currently, such goal setting has de facto reverted to the states and areawide agencies. What exists, as a consequence, is a patchwork quilt of management perspectives and a variety of approaches to the problem of watershed management. In a situation where a scientific consensus doesn't exist it is perhaps useful that a variety of approaches does exist. However, without a conceptual framework with which to judge the effectiveness of these approaches there is no way to assess their comparitive merits. Restoring the chemcial, physical, and biological integrity of the nation's waters requires knowledge of the structural and functional characteristics of natural aquatic ecosystems and the adoption of a systematic set of biologically based goals.

Organic Sediments

Two broad classes of sediments can be distinguished, organic and inorganic. For the purposes of characterizing in-stream impacts of organic sediments we will outline the work of Ken Cummins (1975), and James Karr (1977a, 1977b).

Cummins (1974, 1975) proposed a process-oriented, functional framework for for analyzing running water environments. The framework describes stream systems as a continuum beginning with first, second and third order streams typical of headwater environments through mainstem streams segments. As part of our slide presentation we will follow a typical midwestern stream system (Hickory Creek) from a first order stream reach through its confluence with the Des Plaines River at which point it represents a fifth order stream. Cummins distinguishes the various physical, chemical, and biological differences characteristic of the transition in stream order. A summary of these differences is given in table No. 1 and diagramed in Fig. No. 1.

Headwaters portions of streams (first, second, and third order reaches) are dominated by inputs from stream-side vegetation. Energy input into the system derives from leaf fall, twigs, etc. Levels of sunlight, especially during the late spring and summer, are greatly reduced by the overhanging vegetative cover and as a consequence comparitively little "primary production" in the form of algal communities originates in this portion of the stream. For the same reason temperature fluctuations in these reaches are more moderate. Coarse Particulate Organic Matter (CPOM) which is deposited is processed by a community of bacteria, fungi and macroinvertebrates adapted to this type of organic base. Macroinvertebrate communities are dominated by "shredders" capable of dissecting and processing leaves and twigs (CPOM). The ratio of photosynthesis to respiration is less than one in these headwater reaches, indicating that the system has a heterotrophic energy economy dominated by the import of organic matter from the contiguous terrestrial communities. As a consequence of the processing of macroinvertebrate communities CPOM is broken down and fragmented into finer particles or Fine Particulate Organic Matter (FPOM) which is subsequently transported downstream. Coarse sediments in the form of rubble and gravel dominate the bottom surface of the stream. Fish communities are characterized by headwaters species which are largely insectivorous. Cummins (1975) has estimated that the biota processes about 80 percent of the Particulate Organic Matter (POM) and 50 percent of the Dissolved Organic Matter (DOM) in first through third order streams.

In mid-reaches of the stream continuum (fourth through sixth order streams) the basic energy economy of the system shifts. Stream width increases, overhanging vegetation no longer provides dense shading, and available light and substrate increase to the degree that substantial primary production can now take place. The ratio of photosynthesis to respiration shifts to a value greater that one indicating that the system is no longer predominately heterotrophic. Upstream import of both CPOM and FPOM is still taking place with FPOM the dominant variety of import material. As a consequence a varied assemblage of macroinvertebrates inhabit these reaches. Grazers, which feed off algal forms originating in these reaches, are an addition to the invertebrate fauna, and a variety of "collectors" or filter feeders is common. Fish populations include insectivores and piscivores (fish eaters).

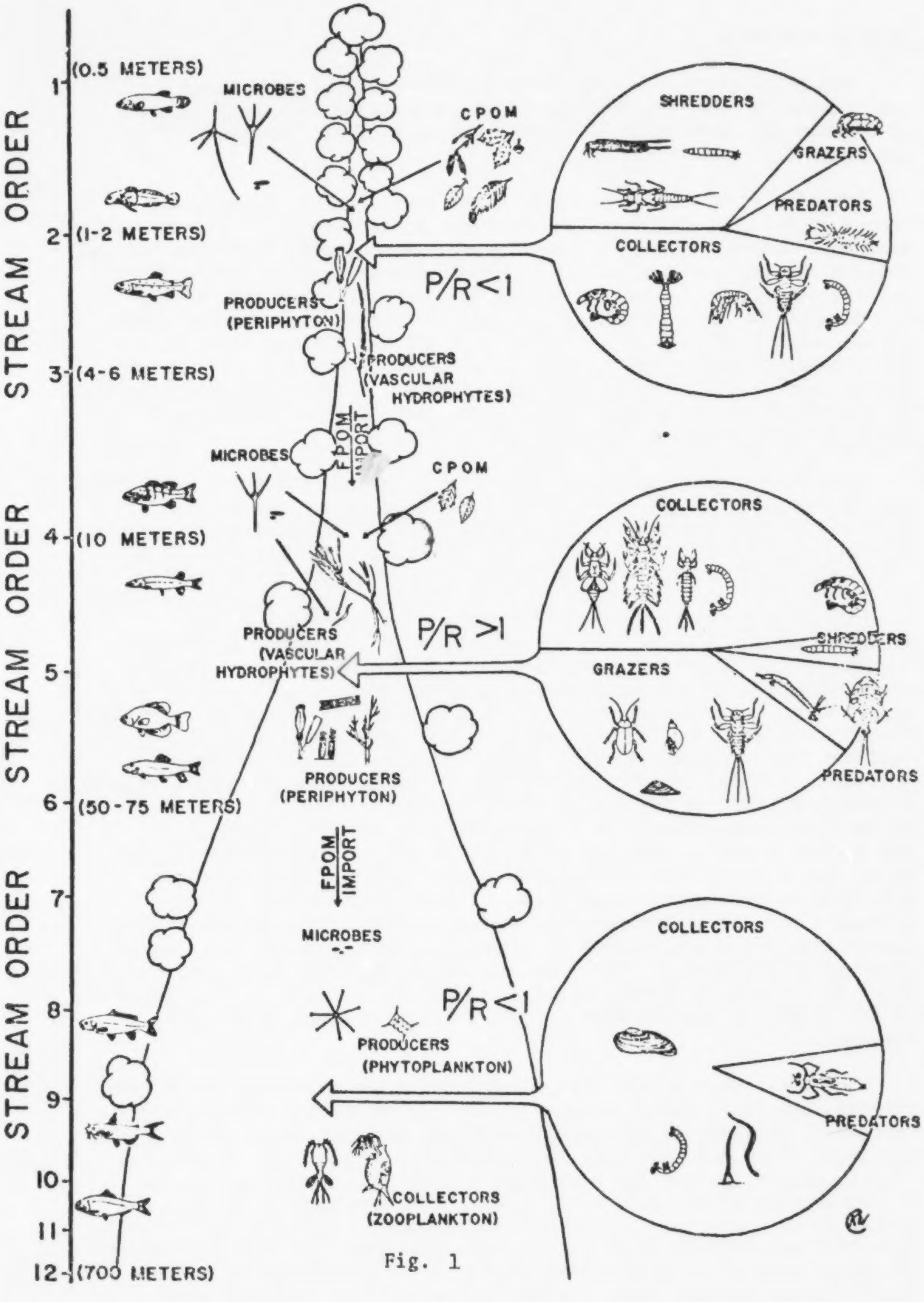

STREAM ORDER
STREAM ORDER
STREAM ORDER
1
(0.5 METERS)
2
(1-2 METERS)
3
(4-6 METERS)
4
(10 METERS)
5
6
(50-75 METERS)
7
8
9
10
11
12
(700 METERS)
MICROBES
CPOM
SHREDDERS
GRAZERS
PREDATORS
COLLECTORS
P/R<1
PRODUCERS
(PERIPHYTON)
PRODUCERS
(VASCULAR
HYDROPHYTES)
FPOM
IMPORT
MICROBES
CPOM
COLLECTORS
P/R >1
SHREDDERS
GRAZERS
PREDATORS
PRODUCERS
(VASCULAR
HYDROPHYTES)
PRODUCERS
(PERIPHYTON)
FPOM
IMPORT
MICROBES
COLLECTORS
P/R<1
PRODUCERS
(PHYTOPLANKTON)
PREDATORS
COLLECTORS
(ZOOPLANKTON)

Fig. 1

Figure 1. A theoretical diagrammatic representation of certain changes in structure function in running water ecosystems from headwater to the mouth (stream order shown at the left). The organisms pictured are merely possible representatives of the functional groups shown (A). The decreasing direct influence of the adjacent terrestrial component of the watershed and increasing importance of upstream import from the headwaters (B, orders 1-3) to the mouth is a basic feature of the system. Coupled with this is a decrease in shredders and an increased dominance of collectors. The mid-region of the river system is seen as the major region of primarily production (growth of green plants) and associated grazer populations (C, orders 4-6). The lower reaches become more turbid with increased importance of plankton (D, orders 7-12). The fishes are dominated by invertivores in the headwaters, and piscivores in the larger sections with planktivores important in the highest order.

From K.Cummins,1975;"The Ecology of Running Waters;Theory and Practice", in _Proceedings of the Sandusky River Basin Symposium_

Table 1. General characteristics of running waters clustered into three stream order groupings.

Stream Orders	Size	Heterotrophy Autotrophy	Organic Matter Inputs of Terrestrial Origin	Primary Production	Light Regime	Temperature Regime	Dominant Sediments
1-3	Small, head-water springs and streams.	Heterotrophic (P/R <1, see Table 2).	Of major importance. Coarse particulate organic matter (CPOM) dominant.	Of minor importance; some algae and mosses.	Heavily shaded.	Lesser daily temperature fluctuation (shading and groundwater effect).	Coarse
4-6	Medium sized rivers.	Autotrophic (P/R >1, (see Table 2).	Of moderate importance. CPOM less significant, fine particulate organic matter (FPOM) from upstream of greater importance	Of major importance; algae and vascular hydrophytes	Little shading, good light penetration.	Greater daily temperature fluctuation (open, less groundwater effect).	Coarse and fine.
7-12	Large rivers.	Heterotrophic (P/R <1, (see Table 2).	Of minor importance. FPOM from upstream dominant	Of moderate to minor importance; primarily planktonic.	Little shading, poor light penetration due to turbidity.	Lesser daily temperature fluctuation (moderation by large volume)	Fine

From K.Cummins,1975;"The Ecology of Running Waters;Theory and Practice",
in Proceedings of the Sandusky River Basin Symposium

Further downstream (seventh to twelveth order) the stream energy economy again shifts and becomes heterotrophic. The stream has become deeper, it has collected more upstream sediments, it has a higher nutrient load, and attached algal forms are no longer as common as they were in the mid-reaches. The increased turbidity reduces light penetration, the potential for photosynthesis is reduced, and substrate availability is reduced for bottom attachment of periphyton. Primary production and photosynthesis take place through free floating algal forms and a greater diversity of planktonic forms develop. The macroinvertebrate community is dominated by "collector" organisms. Fish populations of the large rivers will include a large variety of planktivores along with other varieties of fish eating and insect eating species. It will be apparent that regional and seasonal variations must be superimposed on Cummins archtype.

Potential implications of such a functional-process oriented framework for stream management become apparent if we consider the decision to locate a sewage treatment plant outfall pipe. A sewage treatment plant discharges DOM and FPOM from its outfall pipe. The impact of such materials for the in-stream energy economy and the fisheries and macroinvertebrate communities would require not only a consideration of concentrations of chemical parameters but an estimation of overall organic loads, a consideration of the position of the outfall pipe along the stream continuum, and a gauging of the significance of the sewage treatment plant organic discharge against "normal" or "typical" in-stream organic loads.

Karr and Dudley (1977a) adopted the major elements of Cummins framework to analyze point and non-point source impacts to Black Creek, an agricultural watershed in Northeastern Indiana, which had been targeted as a demonstration basin for the application of agricultural best management practices. Their analysis indicated that Black Creek had shifted to an autotrophic system through considerable portion of its length instead of maintaining the "normal" heterotrophic energy economy. Ecological factors which they felt were tied to resource degradation included the following (modified from Karr and Dudley, 1977a):

1. Large comparitive contributions of FPOM from sewage treatment plants

2. Large comparitive contributions of simple nutrients from both point and non-point sources.

3. Loss of stream side vegetation with subsequent increases in in-stream solar energy, and a reduction in input of CPOM. Algal populations increase in response to this and item #2.

4. Exageration of temperature and dissolved oxygen values as a consequence of the loss of stream-side vegetation.

5. Ditching, channelization, and drainage manipulations resulting in the loss of in-stream habitats and substrates.

6. Removal of natural vegetation and the construction of drainage networks resulting in the alteration of seasonal drainage patterns.

Karr and Dudley (1977a) reemphasized in their study that the biological integrity of a watershed can only be gauged by a functional/structural framework which looks at the three major classes of variables impacting stream systems. These variables include a characterization of: 1) the energy relationships of the system 2) the water quality of the system and 3) the character of the habitat. An approach which looks at only one of these areas will be doomed to failure since the other factors have the ability to impact the biological integrity of the system being considered.

Impacts of Inorganic Sediments

Several comprehensive literature reviews on the effects of sediment on biota have recently been published by the USEPA (cf. "Impacts of Sediment and Nutrients on Biota in Surface Waters of the United States", Farnsworth et. al, 1979; and "Effects of Suspended Solids and Sediment on Reproduction and Early Life of Warmwater Fishes", 1979, Muncy et.al). Sediment per se has long been recognized as a potential pollutant. Smith (1971) estimated that "silt" (largely of agricultural origin) was the principal factor involved in the destruction of Illinois native fisheries. He judged that 2 species of fish had been decimated and 14 species had undergone range reductions as a consequence of the impacts of silt. Milton Trautman (1957), the chronicler of Ohio fisheries history, similarly states, "Studies made since 1925 have proved that since then, if not before, soil suspended in water has been the most universal pollutant in Ohio, and the one which has most drastically affected the fish fauna."

Inorganic sediments are generally assigned on the basis of size and physical method of transport to:

1. Suspended load: particles maintained in the water column by turbulence and carried with the flow of water; and

2. Bed load: particles resting on the stream bed and pushed or rolled along by the flow of water.

Suspended loads typically are compromised of silts and clays supplied by the watershed. Bed load is composed of larger particles including sand and gravel which are not typically a part of the water column. Biotic impacts of bed load movement are generally attributable to abrasion, scour, and burial. Suspended load increases turbidity, and may interfere with photosynthesis and/or respiration. Impacts of sediment on biota as described in Farnsworth, et.al, 1979 and Muncy et. al, are summarized in Table No. 2. Farnsworth, et.al (1977), indicate that a number of factors interact with sediments to determine the ultimate impact on a particular ecosystem. Such factors include discharge, temperature, bottom type, light, nutrients, pesticides, metals, and dissolved gases. These factors interact confounding an explicit reading of the impact of sediments on the biota.

TABLE NO. 2 BIOTIC IMPACTS of SEDIMENT as ADAPTED from FARNSWORTH et.al. (1979) and MUNCY, et. al. (1979)

TROPHIC LEVEL	IMPACT
PRIMARY PRODUCERS (Attached algal forms planktonic algal forms, and macrophytes)	Increase in turbidity of water column with subsequent reduction in photosynthetic activity
	Increase in associated nutrient levels with subsequent increase in algal growth
	Siltation of microhabitats and substrates resulting in a reduction in attached algal forms.
	Scouring and abrasion of microhabitats resulting in a reduction of attached algal forms
	Impacts on primary producers as a consequence of associated heavy metals and or toxics
MACROINVERTEBRATES	Avoidance of adverse conditions by migration, and drift
	Increased mortality from sedimentation due to physiological effects, burials, and physical destruction.
	Reduced rates of reproduction resulting from physiological effects, changes in suitable substrates, and loss of early life stages
	Modified rates of growth and reproduction caused by habitat modification and changes in type and availability of food.
FISHERIES	Modification of natural movements, habitat exploitation, and migration patterns.
	Increased mortality of adults and juveniles resulting from abrasion an smothering of gill tissue by fine sediment. This may also act indirectly in the form of decreased resistance to stress.
	Suppressed development of fish eggs and larvae
	Reduced abundance and availability types of food with subsequent chnages in species composition and biomass.

Muncy, et.al. (1979) extensively reviewed the literature on the impacts of sediment on fisheries. Early field studies equated extremely high suspended sediment concentrations with direct mortality. More recent studies have indicated that different species and year classes of fishes are not equally susceptible to various types and levels of suspended sediments. The authors conclude that the large volume of studies done to date describe "indirect evidence" of the impacts of sediment. They propose that substantial controlled laboratory studies are needed to elaborate and corroborate suspected fisheries impacts.

As with organic sediments the resource manager is faced with problem of determining what is a "normal" or "allowable" sediment load and what is an "acceptable" biological response. Existing allowable sediment yields have been defined by the Soil Conservation Service for various types of soils, agricultural practices, and topography. Farnsworth, et.al. (1979) suggest the formulation of regional goals based on biogeographic or ecological regions. We wish to reiterate the need for adoption of a systematic set of goals based in a review of functional/structural biological perspectives.

REFERENCES

Cummins, K.W. 1974. "Structure and Function of Stream Ecosystems," Bioscience. 24:631-641

Cummins, K., 1975, "The Ecology of Running Waters, Theory and Practice" in Proceedings of Sandusky River Basin Symposium, Ed. D. Baker et. al., Pub. of Int. Joint. Commission p. 277-293

Farnsworth, E. et.al., 1979, Impacts of Sediment and Nutrients on Biota In Surface Waters of the United States, USEPA pub. EPA-600/3-79-105

Karr, J. and Dudley, D. 1977(a), "Biological Integrity of a Headwater Stream: Evidence of Degradation, Prospects of Recovery," in Environmental Impact of Land Use on Water Quality; A Final Report on the Black Creek Project, Ed. J. Morrison, USEPA pub., EPA-905/9-77-007

Karr, J. and Schlosser, I, 1977(b), Impact of Nearstream Vegetation and Stream Morphology on Water Quality and Stream Biota, USEPA pub., EPA-600/3-77-097

Muncy, R. et.al, 1979, Effects of Suspended Solids and Sediment on Reproduction and Early Life of Warmwater Fishes: A Review, USEPA pub. EPA-600/3-79-042

Smith, P. 1971, Illinois Streams: A Classification Based on Their Fishes and on Analysis of Factors Responsible for Disappearance of Native Species, Bio. Notes no. 76, pub. Ill. Nat. History Survey, 14p.

Trautman, M. 1957, Fishes of Ohio, Ohio State Univ. Press., Columbus Ohio, 683p.

Warren, C., 1979, Toward Classification and Rationale for Watershed Management and Stream Protection, USEPA pub. EPA-600/3-79-059

CONFERENCE SUMMARY

Clifford Risley, Jr.
Senior Science Advisor
Surveillance & Analysis Division
US EPA, Region V
Chicago, IL 60605

My closing remarks are to be a summary of the highlights of this seminar. I want to apologize to all of the speakers whom we had to cut short. We knew this would happen. We took a deliberate risk when we planned this seminar. We knew, when we put it together and when we invited these speakers; the kinds of work they have been doing; the importance of their work; and we knew that it was impossible for them to cover their experience in such a short time. We wanted, though, to expose you to this particular variety of people so that you would be aware of what they have been working on and what their experiences have been.

We are going to put out a seminar publication. The complete text of the seminar papers will be in this publication so that any of the papers which have struck you as being of particular interest to you will be readily available to you. This is one way in which you can go a little further into the work that has been undertaken.

Another way open to you, now that you have been introduced to these people, will be for you to personally follow up with them concerning those areas which are benefical to you. This can benefit the work in two ways. You can go to them for their knowledge and their help and also you can go to them with your experiences and your inputs to their work.

The same opportunity exists to contact those of us who work in the management areas in EPA and in the state and local regulatory agencies. We can all benefit from this exchange of ideas. We feel that the greatest outcome of this seminar is to stimulate such an exchange and find out who is doing what.

Until recently, the non point source work has been taking a back seat in EPA. In going back far enough into the fifties and sixties, before the kind of legislation we have today, those of us who go that far back were involved in looking at stream water quality; looking at water quality criteria, ways to improve quality and the costs of cleanup; the very things we were talking about here today. However, there is no doubt in my mind, for those of us who had that experience, that we were then greatly concerned about point source pollution. Where we had uncontrolled point source pollution, our streams were being seriously affected.

The legislation of 1972, the Water Quality Acts, properly, I think, put the focus on the point source pollution and said: "we have to eliminate point sources." Congress said, in effect: "we have to require everyone to go to secondary treatment. We have to eliminate the industrial discharges." And they set up the mechanism of enforcement powers and grants in order to do this.

I think the decade of the 70's was, then, the decade of enforcement. In the seventies we said: "Let us go out and put a stop to all these discharges." We are pretty well into that process. Now, we are far enough along that we have discovered that we have other inputs. I don't think we realized how much of a contribution we got from non point inputs back in the sixties. We learned this during the seventies while many of us were still working on these problems. At the same time we felt frustrated that we couldn't do anything about it.

The agency is now taking the view that: "We have done all this point source pollution work and we still have degraded water quality! Why? The agency realizes that non point source pollution is there and some controls have to be made.

We are still moving forward and I am looking forward to the decade of the eighties, when we look again at water quality with renewed knowledge. We know, now, many of the things that we have to do to achieve better water quality. We are going to go back to more monitoring despite the views of one of the speakers who said "monitoring is not working and what we need to do is modeling." I think monitoring is important and we are going to go back to doing more monitoring.

That is not to say that modeling is not important. The fact of the matter is, that since the publication of PL 92-500, the EPA has not had an adequate management model to serve as a guideline to the states to evaluate non point source pollution. We feel that a process is urgently needed to evaluate non point pollution abatement costs and compare them to conventional point source abatement costs. You have heard this before. This is what I started off the Seminar by saying. This is why we had this seminar: to stimulte the development of another model, if you will, only this model is to be a desk top model that we could all use to get a handle on the trade offs--the management trade offs.

The emphasis on this seminar has been to this end. We have heard many good inputs describing what some of these trade offs are. I was pleased to find that many of the speakers are aware of this and they are suggesting various trade offs in their area of specialization. I think the message is there, across the board, in all of our areas of expertise.

Following are some additional points made during the seminar that I feel are worthy of repeating, for emphasis. Basically what did the seminar say? Well, it says: "What are we going to emphasize in each basin? In one basin controlling waste water treatment plants might be the major impact and maybe that's all we need to control. In another basin, control of point sources may not be of any great consequence at all, and we have to go back and look at the impacts of "the cornfield," if you will, and determine the erosion loss in a certain sector. We have learned that in some of these basins, you don't have to clean up an entire basin. All you have to do is find the critical areas and put your best management practices to work in those few critical areas. All of this says that we have to integrate point source and non point source in all kinds of management. It all has to be integrated. We must all get the big picture and start looking at all phases of it before we enter into the final decision making.

Don Urban once said to me, that we have been spending 45 years trying to get the land owners to implement best management practices. We were doing it on the basis of saving their own land. We didn't get very far with that. Now we want them to implement best management practices to protect our vital water resource, and we're not going to get any place with them again, on the same basis we have tried to for the last 45 years. That is, to expect them to do this strictly on a voluntary basis.

So, I think we have to do things like they did in Black Creek. To find what it is that makes good sense to the landowners and what the incentives are to get the landowners involved in this process. It means we have to obtain some monetary support for them. We must provide a lot of guidance; a lot of loving and tender care, which was best said by Dan McCain when he explained the process he went through working with the landowners. He said that he had to get out there and marry them. He had to live with them every day and help guide this process. I think that in order to make the whole process work, when it comes to best management practices, this is what you are going to find. If you have somebody at the local level who understands the problem and who is willing to get in there and work like this, then something can happen. If you have nobody like this at the local level, I don't think somebody sitting in Chicago, behind the desk, saying this is a good plan and this is the best model, is going to have any effect at all. An even less effect will be accomplished from Washington deciding that if we spend a million dollars on three or four projects, it is going to solve our problem. No way. We have to get to the local level to get the kind of program that will work there. This is not to say that we don"t need the planners and the modelers and the professors. We do. We have to have this kind of thinking behind it to guide the way.

One of the things that came out in the Seminar is the fact that we have been tripping over each other models. Everybody comes up with their model and thinks this is the way to go and the only way to go and I think that it came very clear to me that there are several models that are very valuable and they are valuable for different purposes. We should make use of these.

We shouldn't get so involved in one particular approach that we think we've got the only answer. We can modify what we are doing. If we are working on a large scale basis, we need one kind of model and if we are working on a smaller scale basis we need another kind of model. We need to use the small scale model to get better inputs to use on our larger model.

With all these approaches come criticism of what someone did in the past, or what they are doing now, or what they didn't do. I know, and you know, that we all do as much as we can within the resources that we have. I don't think we should criticize somebody for not having done something more than they did. I think they have all done the best they could from their own geographic area, their own particular background and training. All of these inputs--and I think we heard a great many of them from different sources today--all of them are valuable to us. I think we should embrace the expertise and the outputs of these experts and make use of them in solving our own particular problems.

I want to thank all of you who have stayed through to the end. I applaud you for this.

I want to applaud all the speakers and the moderators for their presentations. I think they were excellent.

I hope that we have provided you with an update on the need for integrated planning and consideration of integration and trade offs in your decision making. We tried to introduce you to some of the Who's Who in the forefront of Water Quality Management and what they have been doing, and as I said before, I hope you will follow up on this seminar by contacting these people and letting them know what you think of what they are doing, and let them know what you are doing.

Let's work together to try to achieve the goal of clean water tht we have all been working toward. Thank you all again. This officially closes the seminar.

Attendees for September 16-17 Seminar
Pick Congress Hotel, Chicago, IL

John B. Adams
Director, Environment and Food Regulatory Affairs
National Milk Producers Federation
30 F. Street, N.W.
Washington, D.C. 20001

John R. Adams
U.S. Army Engineer District
Buffalo, NY 14127

Mark Alderson
U.S.EPA-5WWQ
230 S. Dearborn
Chicago, IL 60604

David Beasley
Ag. Eng. Dept.
Purdue University
W. Lafayette, IN 47907

Howard Allen
Project Hydrologists
U.S. Geological Survey
Post Office Box 427
DeKalb, IL 60115

Joan G. Anderson
PCB
309 W. Washington
Chicago, IL 60606

David Baker
Professor
Heidelberg College
Tiffin, Ohio

Joan Balogh
1815 University Avenue
Madison, WI

Dr. Michael J. Barcelona
Head Aquatic Chemistry Section
IINR-State Water Survey Division
Box 232
Urbana, IL 61801

Jim Baumann
Wisconsin Department of Natural Resources
Post Office Box 7921
Madison, WI 53711

John Beeker
Environmental Planner
NOCA
1501 Euclid Avenue
Cleveland, OH 44115

Bob Bellandi
Asst. Proj. Director
Central NY Regional Plan. and Dev. Bd.
700 E. Water Street
Syracuse, NY 13210

William Benjey
USEPA-Region V
Chief, Ohio Water Quality Mgmt. Section
230 S. Dearborn
Chicago, IL 60604

James Bland
USEPA-Region V
Ohio Water Quality Mgmt. Section
230 S. Dearborn
Chicago, IL 60604

Lee Cunningham
Administrator Assistant
Illinois Pollution Control Board
309 W. Washington Street
Chicago, IL 60606

Tom Davenport
Environmental Protection Agency
2200 Churchill Road
Springfield, IL 62706

Jon V. DeGroot
Assistant State Conservationist
USDA Soil Conservation Service
316 N. Robert Street, Room 200
St. Paul, MN 55101

Basin Dihu
S&A-CDO, IL/IN Field Inv. Section
536 South Clark Street
Chicago, IL 60605

Roderick A. Dorich
Grad Research Assistant
Purdue University, Agry Dept.
West Lafayette, IN 47907

Ron Drynan
Senior Engineer
Great Lakes Regional Office, IJC
Windsor Ontario, Canada

Jacob D. Dumelle
Chairman, IL Pollution Control Bd.
309 W. Washington Street
Chicago, IL 60606

Doug Ehorn
USEPA-5WQM
Chief, Michigan Water Quality Mgmt. Sec.
230 S. Dearborn
Chicago, IL 60604

Mr. Richard Cahill
Associate Chemist
Illinois State Geological Survey
322 Nat. Res. Bldg.
Urbana, IL 61801

Randolph O. Cano
Project Officer
USEPA-Region V-5WWQM
230 S. Dearborn Street
Chicago, IL 60604

Howard Essig
Illinois EPA
1701 First Avenue
Maywood, IL

Ronald C. Flemal
Professor of Geology
Northern Illinois University
Dept. of Geology
DeKalb, IL 60115

Christopher R. Freeman
Environmental Planner
MACOG
1120 County-City Bldg.
South Bend, IN 46601

Jeffery Gagler
Water Quality Modeler
USEPA-Water Quality Policy Section
230 S. Dearborn
Chicago, IL 60604

Robert Gallucci
Monroe County Pure Waters
65 Broad Street, Room 100
Rochester, NY 14614

James R. Gammon
Professor of Zoology
DePauw University
Greencastle, IN 46135

Albert A. Almy
Department of Public Affairs
Michigan Farm Bureau
Post Office Box 20960
Lansing, MI 48909

Ralph G. Christensen
Ecologist
Great Lakes National Program Office
USEPA-Region V
536 South Clark Street
Chicago, IL 60605

Roy Christenson
WDNR
26 Breese
Madison, WI

Mary Cocklan
P.O. Box 68
Maple Park, IL 60151

Evelyn Cooper
Surveillance and Analysis Division
USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

Terry E. Cox
IL Pollution Control Board
309 W. Washington, Rm. 300
Chicago, IL 60606

John Crumerine
Manager, Honey Creek Watershed Project
Tiffin, OH

Elizabeth Cunningham
Environmental Engineer
CT 208 Program
Post Office Box 1088
Middletown, CT 06457

Jeffery B. Bode
WDNR
Milwaukee S.E., WI 53213

Susan Boldt
USEPA-5WWQM
230 S. Dearborn
Chicago, IL 60604

Dan Bondy
Great Lakes Regional Office, IJC
Windsor Ontario, Canada

James Bosch
Mgr. Env. Engineering
Land O Lakes, Inc.
614 McKinley Place
Minneapolis, MN 55413

Donald E. Brand, P.E.
Project Officer
Balto. Co. Dept. of Health
401 Bosley Ave. - 4th Floor
Townson, MD 21204

Charles Brasher
USEPA-5WWQM
230 S. Dearborn
Chicago, IL 60604

James Brentlinger
Fieldman
State Soil & Water Conservation Commit.
Room #7, AGAD Bldg. Purdue Univ.
West Lafayette, IN 47907

Marcia (Marcy) Brooks
Environmental Programs Coordinator
South Central MI Planning Council
70 E. Michigan
Galesburg, MI 49053

Bill Elman
FUWQPA
Neenah, WI

Wayne Elson
USEPA-5WWQM
230 S. Dearborn
Chicago, IL 60604

Gary Erickson
Regional Fishery Biologist
Illinois Department of Conservation
110 James Road
Spring Grove, IL 60081

Wayne Gorski
USEPA-5WWQM
230 S. Dearborn
Chicago, IL 60604

Jon T. Grand
WDNR
4049 Cherokee
Madison, WI

John R. Gray
Project Hydrologists
U.S. Geological Survey
Post Office Box 427
DeKalb, IL 60115

Dr. David Gross
Associate Geology
Illinois State Geological Survey
264 Nat. Res. Bldg.
Urbana, IL 61801

Edwin Hammett
Director of Regional Planning
TMACOG
123 Michigan St.
Toledo, OH 43624

Albert Horner
Eng. Qual. Manager
S. Carolina Dept. Env. Control
2600 Bull Street
Columbia, SC 29210

Linda A. Gawthrop
USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

Raymond Giese
Project Officer
USEPA
230 S. Dearborn Street
Chicago, IL 60604

Irvin G. Goodman
Illinois Pollution Control Board
309 W. Washington, Room 300
Chicago, IL 60606

Thomas M. Heidtke
GLBC
Ann Arbor, MI

Bob Hennigan
Project Director
Central NY Regional Plan. & Dev. Bd.
700 E. Water Street
Syracuse, NY 13210

Henry J. Hess
Chem. Engineer
CDO, S&A Div. USEPA
536 South Clark St. Room 1008
Chicago, IL 60605

Harlan Hirt
USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

J.S. Horn
717 Birch Road
Lake Bluff, IL 60044

James Hanlon
USEPA-5WEEB
230 S. Dearborn
Chicago, IL 60604

William J. Horvath
Regional Representative
Nat. Assoc. of Conservation Districts
1052 Main Street
Stevens Point, WI 54481

George Horzepa
Acting Program Manager
NJ Dept. Envir. Prot. Water Resources
P.O. Box CN-029
Trenton, NJ 08625

Larry F. Huggins
Professor
Purdue University
W. Lafayette, IN

Garth Jackson
University of Michigan
Ann Arbor, MI

Eileen L. Johnston
Environmental Educator
505 Maple Avenue
Wilmette, IL 60091

Robert S. Jonas
39 Rockhill Road
Rochester, NY 14618

Don Josif
WQMP-USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

Chun-Wei Kao
Research Associate
Michigan State University
Crop and Soil Science Dept.
East Lansing, MI 48824

John A. Killam
R. 1
Jacksonville, IL 62650

Peggy Harris
USEPA-5GLNP
536 South Clark Street
Chicago, IL 60605

Jonathan Harsch
The Christian Science Monitor
100 N. LaSalle St. #600
Chicago, IL 60602

Joe B. Hays
RC&D Coordinator
Hoosier Heartland RC&D
54 Boone Woods
Zionsville, IN 46077

Al Krause
Environmental Scientist
USEPA-5WEEB
230 S. Dearborn
Chicago, IL 60604

Joe Kruz
Aquatic Biologist
Wisconsin Department Natural Resources
P.O. Box 13248
Milwaukee, WI 53213

Madeline Lewis
USEPA-5WQMB
230 S. Dearborn
Chicago, IL 60604

Terry Logan
Professor
Ohio State University
Columbus, Ohio

John Lowrey
Soil Conservationist
USDA-SCS
P.O. Box 475
Lisle, IL 60532

Darrell McAllister
IDEQ
Des Moines, Iowa

Dale Luecht
USEPA-WD
230 S. Dearborn
Chicago, IL 60604

Richard W. Lutz
Head Impact Analysis Section
Div. of Planning, IL Dept. Conservat.
601 Stratton Bldg.
Springfield, IL 62706

Noel W. Kohl
Chief, IL/IN Wqm. Section
USEPA-Region V, Water Division
230 S. Dearborn
Chicago, IL 60604

Ron Kolzow
USEPA-Region V
Chicago, IL 60604

Madonna F. McGrath
Director, Great Lakes National Program
Office
USEPA-5GLNP
536 S. Clark Street
Chicago, IL 60605

Donald M. McLeod
VA State Water Control Board
Roanoke, VA 24019

Steven E. Mace
Wisconsin DNR
P.O. Box 13248
Milwaukee, WI 53226

Michael MacMullen
Chief, Water Quality Policy Section
USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

Bob Kirschner
NIPC
400 W. Madison
Chicago, IL 60606

David Klinedinst
Ill Dept. Cons
Springfield, IL

LeLand J. McCabe
Director, Epidemiology Div.
USEPA-HERL
Cincinnati, Ohio

Dan McCain
District Conservationist
USDA-SCS
Fort Wayne, IN

Edward G. Maranda
Twin Cities Metropolitan Council
300 Metro Square Bldg.
St. Paul, MN 55101

Russell J. Martin
USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

Bob Martini
Water Quality Analyst
Wisconsin DNR
Box 818
Rhinelander, WI 54501

Gertrude Matuschkovitz
Environmental Protection Specialist
USEPA
230 S. Dearborn Street
Chicago, IL 60604

Orville Macomber
Environmental Engineer
USEPA-CERI
11280 Foremark Drive
Cincinnati, OH 45241

Peter G. Meier
Associate Professor
The University of Michigan
2516 SPH 1, 109 Observatory
Ann Arbor, MI 48109

Tom Mitchell
Water Resources Planner
USEPA
230 S. Dearborn Street
Chicago, IL 60604

E.J. Monke
Ag. Eng. Dept.
Purdue University
W. Lafayette, IN 47907

Tim Montieth
Water Resource Engineer
GLBC
Ann Arbor, MI

Ron Mustard
Director, Office of Environmental Review
USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

Michael T. Phillips
Senior Env. Planner, Water Div.
USEPA
230 S. Dearborn Street
Chicago, IL 60604

John Piccininni
USEPA-Region V
230 S. Dearborn Street
Chicago, IL 60604

Fred Madison
Project Director
Washington Co. Project
U. of Wisconsin
Madison, Wisconsin

Larry I. Madsen
Wheatland, ND

Joe Magner
Soil Scientist
MN Pollution Control Agency
1935 W. County Road B-2
Roseville, MN 55113

James L. Magruder
Ground Water Age
Elmhurst, IL

Thomas F. Maher
Environmental Engineer
USEPA-Region II
26 Federal Plaza
New York, NY 10278

John S. Nagy
Project Officer
USEPA Region V
230 S. Dearborn St. 5WWQ
Chicago, IL 60604

Vladimir Novotny
Associate Professor
Marquette University
1515 W. Wisconsin
Milwaukee, WI 53233

Jeffery Nedelman
Administrative Assistant to Senator Gaylord Nelson
Wisconsin

Nancy Prehler
USEPA-5GLNP
536 S. Clark Street
Chicago, IL 60605

Barry O'Flanagen
WDNR
Box 7921
Madison, WI 53207

Bernie Orenstein
USEPA-Region V
230 S. Dearborn Street
Chicago, IL 60604

Jame Pendowski
EPA
2200 Churchill Road
Springfield, IL 62706

Mary Ann Rodewald
USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

Richard Rising
Senior Planner
Monroe County Dept. of Planning
39 W. Main Street
Rochester, NY 14614

Clifford Risley
Senior Science Advisor
USEPA-Region V
536 S. Clark Street
Chicago, IL 60605

J. H. Rolfes
One Wheaton Center, Suite 1901
Wheaton, IL 60187

Angela H. Preston
Water Quality Coordinator
Indiana Heartland Coording Com.
7212 N. Shadeland Ave., #120
Indianapolis, IN 46250

Hoody Price
Seminole County Planning
Courthouse
Sanford, FL 32771

J. Steve Reel
Assistant to Director
South Florida Water Management Dist.
P.O. Box V
West Palm Beach, FL 33402

Don Roberts
USEPA-Region V
230 S. Dearborn
Chicago, IL 60604

Phillip D. Peters
Assistant Director
Plans and Programs
Northeastern IL Planning Commission
400 W. Madison Street
Chicago, IL 60606

John Pfender
Water Quality Planner
Madison, WI

Richard Parkin
USEPA-WD WQMB
230 S. Dearborn Street
Chicago, IL 60604

Rob Striegl
Project Hydrologist
U.S. Geological Survey
P.O. Box 427
DeKalb, IL 60115

William H. Sanders III
Director, S&A
USEPA-Region V
536 South Clark Street
Chicago, IL 60605

Wesley D. Seitz
Prof. of Univ. of IL
305 Mumford Street
Urbana, IL 61801

Herb Selbrede
National Milk Producers
Rt. 1
Sparta, WI

Pat Sharkey
IL Federal Liason
IL Pollution Control Board
309 W. Washington
Chicago, IL 60606

Gerald Sipple
RR 3, Box 187
Menomonee, WI

William Sonzogni
Water Resources Scientist
Great Lakes Basin Commission
Ann Arbor, MI

Gary Stewart
Govt. Affairs Coordinator
Michigan Manufacturers Assn.
124 E. Kalamazoo Street
Lansing, MI 48933

Randall Wade
WDNR
1220 Rutledge Street
Madison, WI

A.T. Wallace
CE Dept.
Univ. of Idaho
Moscow, Idaho

David Stringham
Regional Program Coordinator
USEPA-Region V
230 S. Dearborn Street
Chicago, IL 60604

Rose Ann Sullivan
GLBC
Ann Arbor, MI

Jeffrey A. Taylor
Water Resources Engineer
VA State Water Control Board
2111 N. Hamilton Street
Richmond, VA 23230

Mike Terstriep
Engineer, IL Water Survey
Box 232
Urbana, IL 61801

Nelson Thomas
USEPA
9311 Groh Road
Grosse Ile, MI

Lowell Thompson
Metro Council
300 Metro Square Bldg.
St. Paul, MN 55101

Don Urban
Nonpoint Coordinator
EPA-Region V
230 S. Dearborn Street
Chicago, IL 60172

Thomas Windau
Environmental Engineer
FC WQPA
1919 American Ct.
Neenah, WI 54956

Peter Wise
Director, Water Quality Planning Div.
USEPA
401 M. Street
Washington, D.C.

Thomas Warn
Environmental Protection Specialist
USEPA
230 S. Dearborn Street
Chicago, IL 60604

William Wawrzn
State of Wisconsin
Dept. Natural Resources
P.O. Box 13248
Milwaukee, WI 53226

David Wurm
Honey Creek Project
155 E. Perry Street
Tiffen, Ohio

Keith K. Young
Soil Scientist, Soil Technology
Soil Conservation Service
P.O. Box 2890
Washington, D.C. 20013

Bruce Yurdin
Environmental Protection Specialist
IEPA
2200 Churchill Road
Springfield, IL 62706

Mathew Zabik
Professor Pesticides Institute
Michigan State University
Lansing, MI

Greg Zelinka
Madison Metro Sewerage District
Lab Supervisor
104 North 1st Street
Madison, WI 53704

William Withrow
IPCB
309 W. Washington
Chicago, IL

Larry Vendl
Project Hydrologist
U.S. Geological Survey
P.O. Box 427
DeKalb, IL 60115

Terry L. Wells
Senior Planner
Ohio Dept. Nat'l. Resources of Water
Fountain Square, Bldg. E
Columbus, Ohio 43224

Douglas G. Whitaker
Assistant General Manager
The Miami Conservancy District
38 E. Monument Avenue
Dayton, OH 45402

Lyman Wible
Chief Environmental Planner
S.E. Wisconsin Regional Planning
Commission
Waukesha, WI

Carl D. Wilson
Coordinator Nonpoint Source
USEPA-5GLNP
536 S. Clark Street
Chicago, IL 60605